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CLASSIFICATION AND VERTICAL DISTRIBUTION OF THE CHAETOGNATHA OF THE SAN DIEGO REGION

INCLUDING REDESCRIPTIONS OF SOME DOUBTFUL SPECIES OF THE GROUP

BY

ELLIS L. MICHAEL

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(Contribution from the Laboratory of the Marine Biological Association of San Diego)

CONTENTS

PAGE

Introduction 22

Part 1. Systematic 26
- Key to the Genera of Chaetognatha 26
- Key to the Species of *Sagitta* 26
- Key to the Species of *Eukrohnia* 27
- Key to the Species of *Spadella* 27
- Descriptions of the San Diego Species of Chaetognatha 28
- Tabulation and Discussion concerning the Ovaries in some of the San Diego Species 55
- Redescriptions of Some Doubtful Species 64
  - *S. hispida* Conant 64
  - *S. elegans* Verrill 69
  - *S. tenuis* Conant 72
- Brief Description of Species not yet taken from the San Diego Region 73

Part 2. Distribution 77
- Explanation of the Tables of Distribution 77
  - Method of Counting 77
  - Tables of Surface Hauls 79
  - Tables of Horizontal Closing Net Hauls 86
  - Tables of Vertical Closing Net Hauls 92
  - Table of Open Vertical Net Hauls 96

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MAY 4 •

PAGE
General Discussion of the Problems of Plankton Distribution 99
Discussion of the Vertical Distribution of the San Diego Chaetognatha 112
Vertical Distribution of *S. bipunctata* 115
Effect of Day and Night on Vertical Distribution of *S. bipunctata* 117
Variation in Distribution of *S. bipunctata* due to Temperature 128
Variation in Distribution of *S. bipunctata* due to Salinity 133
Seasonal Variation in the Distribution of *S. bipunctata* 139
Effect of Locality on the Distribution of *S. bipunctata* 141
Significance of the Data concerning the Distribution of *S. bipunctata* 143
Distribution of *S. serratodentata* 145
Distribution of *S. lyra* 150
Distribution of Other Species 153
General Summary and Conclusions 157
Bibliography 161

INTRODUCTION

This paper is based upon material collected by the San Diego Marine Biological Station from 1904 to 1909. During this period the station has explored a region lying, in the main, between the parallels of 32° 20′ and 33° 30′ N, and extending from the coast to 119° W. In this material we recognize seven out of eighteen valid species of *Sagitta,* two of the three species of *Eukrohnia* (= *Krohnia* Langerhans), and one of the two species of *Spadella.* The seven species of *Sagitta* are *S. enflata, S. hexaptera, S. lyra, S. serratodentata, S. bipunctata, S. planktonis,* and *S. neglecta. Eukrohnia* is represented by *E. hamata* and *E. subtilis.* The one species of *Spadella* is *S. draco.* Though I have spent much time in detailed and critical examination of this material, I have failed to discover any indication of new species.

The species of *Eukrohnia* and *Spadella* are readily recognized, but those of *Sagitta* are more difficult to identify. The latter naturally fall into two groups, those with and those without collarettes. Although, in the species of each group, the diagnostic characters are annoyingly alike, each species has a definite and distinctive appearance.

It is my aim to give (pls. 1, 2) some idea of this distinctive appearance, in addition to the usual taxonomic characters.

Primarily this depends upon degree of transparency of the species. Doncaster (1902b) has represented this appearance, but his drawings lack accuracy of measurement, which renders them useless for purposes of identification. Most authors, however, have published merely outline drawings and, while accurate in measurements, they do not suggest the distinctive appearance of the species. To make this paper more serviceable to those unacquainted with the group I have endeavored to combine the merits of Doncaster's (1902b) drawings with accuracy of measurement.

Krumbach (1903) has discovered characters of much taxonomic value in the minute anatomy of the seizing jaws, and I have endeavored to extend his descriptions to the San Diego species. This author's contribution merits more attention than it has received, for these hard structures offer the only means of identification applicable to poorly preserved material. It is well to note, however, that to recognize these distinctive characters requires the most delicate microscopic manipulation.

In measuring the curvature of the seizing jaws the following method has been employed. A camera drawing (text fig. 1) was first made. A perpendicular, *ab,* was then erected upon the edge of the jaw at the junction of the shaft, *sh,* with the ventral column, *vent. col.* A second line, *cd,* was then drawn tangential to the point, *pt.* The proportion *ab/cd* indicates the extent of the curvature.

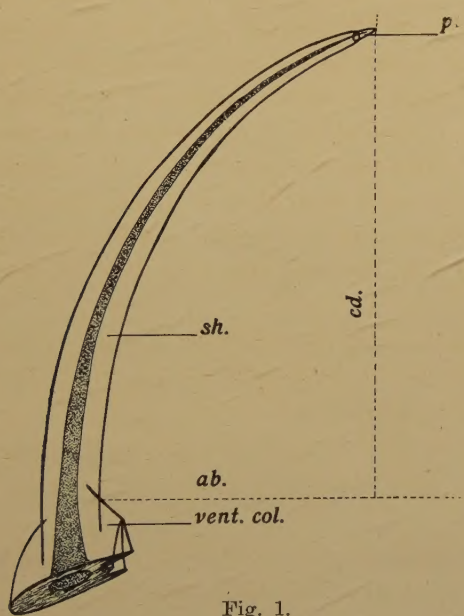

Fig. 1.

In preparing the tables of diagnostic measurements for each species only the most perfectly preserved material has been used. In

specimens not well preserved some characters are always distorted, so that measurements based upon such material can not be relied upon. I have endeavored to include enough measurements in these tables to permit a fairly accurate reconstruction of the outline of each individual considered. All measurements, unless otherwise stated, have been made in proportion to total length of specimen as measured from tip of tail-fin to anterior extremity of head.

In my "Notes on the Identification of the Chatognatha" (1908) I stated that length and shape of ovaries, together with size of ova, could not be depended upon for identification because these organs were the last to develop. While this is partly true, it is their distinctive appearance, together with degree of transparency of the species, that catches the eye and affords the first basis of separation. These differences are brought out in plates 1, 2, 5 and 6. On pages 55 to 64, measurements of the ovaries are tabulated and discussed. However, owing to immaturity of the individuals of some species, it has been impossible to make these tabulations complete.

To facilitate identification, all known species of Chaetognatha are here described. Those obtained from the San Diego region are considered at some length, and the remaining species are briefly described at the close of the systematic part of this paper. In addition a few doubtful species of the group, including *Sagitta hispida, S. elegans, S. arctica,* and *S. tenuis* are redescribed.

While most expeditions have scattered their observations over a large territory, the Marine Biological Station of San Diego has confined its collecting to *one locality.* Until the present we have depended upon surface nets of various sizes and meshes, open vertical nets, the Kofoid closing net (see Kofoid, 1911), and the Kofoid water bucket (see Kofoid, 1905), for the collection of plankton, and on non-registering centigrade thermometers and the Kofoid water bucket for our hydrographic work. While all temperature and salinity determinations made in connection with our hydrographic work are as accurate as the best apparatus permits when in the hands of an expert physicist (see McEwen, 1910), our data could not be made com-

plete without more apparatus. However, our explorations have taught us much regarding methods of collection and apparatus necessary for an adequate quantitative study of plankton distribution. We are convinced that direction and velocity of currents, temperature and salinity of water, wind, clouds, fog, rain, light, and darkness all affect the distribution of plankton *even within a very small area.* The influence of all these conditions must be known to solve any problem concerning the quantitative distribution of plankton. To increase our facilities in meeting this requirement we have recently installed the Ekman (1905a) reversing water bottles, the Nansen vertical closing net (see Herdman, Scott, and Dakin, 1910, p. 275), Richter self-registering deep sea thermometers (see Ekman, 1905a), and the Ekman (1905b) current-meter that records the velocity and direction of currents encountered in deep water. With this apparatus we hope to discover relations in the horizontal and vertical movements of plankton which will be valuable not only to students of planktology, but to the commercial fisheries as well. By strict attention to one locality we have obtained data containing significant facts not present in the results of most expeditions. Following the systematic part of this paper I have discussed these data in so far as they concern the Chaetognatha.

I desire to express my obligation to Professor William E. Ritter, Director of this station, and to Professor C. A. Kofoid of the University of California for suggestions and advice concerning the preparation of this paper. I am further indebted to Dr. G. Herbert Fowler, Secretary of the Challenger Society, to Dr. Hjalmar Broch of the Zoological Institute of the University of Christiana, to Dr. Rudolph von Ritter-Záhony of the Royal Zoological Museum, Berlin, and to the Smithsonian Institution for specimens of a number of rare and doubtful species.

PART I. SYSTEMATIC

KEY TO THE GENERA OF CHAETOGNATHA

1. Two pairs of lateral fins. Two pairs of rows of teeth. Only slight epidermal thickening on body ..... **Sagitta.**
2. One pair of lateral fins, partly on body and tail. One pair of rows of teeth. No epidermal thickening behind head ..... **Eukrohnia.**
3. One pair of lateral fins, entirely upon tail-segment. Two pairs of rows of teeth. Prominent thickening of epidermis, extending from behind head to tail ..... **Spadella.**

KEY TO THE SPECIES OF SAGITTA

1. Species without collarette 2
1. Species with collarette 9
2. Shaft of seizing jaw serrated ..... **Sagitta serratodentata.**
2. Shaft of seizing jaw not serrated 3
3. At least 50 per cent of posterior fin in front of tail-septum 4
3. Less than 50 per cent of posterior fin in front of tail-septum ..... **Sagitta bedoti.**
4. Tail 28 to 40 per cent of total length ..... **Sagitta macrocephala.**
4. Tail 10 to 25 per cent of total length 5
5. Vestibular ridge composed entirely of papillae 6
5. Vestibular ridge provided with usual skeletal parts 8
6. Tail 10 to 14 per cent of total length, mature ovary short, not over 7 per cent of total length ..... **Sagitta gazelle.**
6. Tail at least 15 per cent of total length, mature ovary long, over 20 per cent of total length 7
7. Anterior fin shorter than posterior fin, with large interval between them ..... **Sagitta hexaptera.**
7. Anterior fin longer than posterior fin; in the mature specimens the fins are confluent ..... **Sagitta lyra.**
8. Body transparent. Top of shaft and base of point in seizing jaws converge toward edge of jaw ..... **Sagitta enflata.**
8. Body opaque. Top of shaft and base of point parallel ..... **Sagitta elegans.**
9. At least 50 per cent of posterior fin in front of tail-septum 10
9. Less than 50 per cent of posterior fin in front of tail-septum 14
10. Collarette extending to ventral ganglion ..... **Sagitta planktonis.**
10. Collarette never extending more than half way to ganglion 11
11. Anterior fin extending to ventral ganglion 12
11. Anterior fin never extends to ventral ganglion 13

12. Body transparent. First third of anterior fin without the usual rays ..... **Sagitta pulchra.**

12. Body opaque. Anterior fin with rays throughout.. **Sagitta sibogae.**

13. Tail 28 to 40 per cent of total length. No constriction at tail-septum ..... **Sagitta decipiens.**

13. Tail not over 25 per cent of total length. Constriction at tail-septum evident ..... **Sagitta bipunctata.**

14. Collarette extends to anterior fins 15

14. Collarette never extends much over half way to anterior fins 16

15. Anterior fin longer than posterior fin ..... **Sagitta ferox.**

15. Anterior fin shorter than posterior fin ..... **Sagitta regularis.**

16. Anterior fin extends to ventral ganglion 17

16. Anterior fin never extends to ventral ganglion ..... **Sagitta hispida.**

17. Collarette exceedingly small. Sexually mature at a length from 5 to 6 mm. ..... **Sagitta tenuis.**

17. Collarette well developed, extending nearly half way to ventral ganglion. Never sexually mature under 10 mm ..... **Sagitta neglecta.**

KEY TO THE SPECIES OF EUKROHNIA

1. Lateral fin extends from the region of the ventral ganglion to somewhat behind the tail-septum; never reaches to seminal vesicles; more than 60 per cent in front of the tail-septum ..... **Eukrohnia hamata.**

1. Cephalic limit of lateral fin never more than half the distance from the tail-septum to the ventral ganglion; extends caudally to the seminal vesicles; more than 40 per cent of fin behind septum 2

2. Body width about 4 per cent of total length. Tail 30 to 40 per cent of total length. Seizing jaws evenly curved, 6 to 9 in number. Teeth 9 to 13 ..... **Eukrohnia subtilis.**

2. Body width about 5 per cent of total length. Tail 25 to 41 per cent of total length (usually not over 33 per cent). Teeth 11 to 15. Seizing jaws 6 to 9, with the convex edge made up of two curves, the junction of which makes an obtuse angle at a point about one-fourth the length of the jaw proximad of the tip ..... **Eukrohnia pacifica.**

KEY TO THE SPECIES OF SPADELLA.

1. Average width of collarette nearly half that of body, widest slightly anterior to the tail-septum. Length of fin always less than 5 times its width. Anterior teeth 7 to 10. Posterior teeth 11 to 16 ..... **Spadella draco.**

1. Average width of collarette much less than half that of body; widest slightly posterior to head. Length of fin always more than 5 times its width. Anterior teeth 3 to 5. Posterior teeth 3 to 4 ..... **Spadella cephaloptera.**

Genus **Sagitta**

Sagitta enflata Grassi

Pl. 1, fig. 1; pl. 3, fig. 14; pl. 4, fig. 26; pl. 5, fig. 39; pl. 7, fig. 45; pl. 8, fig. 47.

Sagitta enflata Grassi (1883), p. 16; Strodtmann (1892), p. 18; Béraneck (1895), p. 254; Aida (1897), p. 15; Doncaster (1902a), p. 20; Krumbach (1903), p. 632; Fowler (1906), p. 8.
Sagitta flaccida Conant (1896), p. 85.
Sagitta gardineri Doncaster (1902b), p. 212.
Sagitta brachycephala Moltschanoff (1907), p. 208.
Sagitta inflata, Ritter-Záhony (1908), p. 13; (1909b), p. 5.
Sagitta furcata, Michael (1908), p. 68.

General Appearance

This species is the most transparent of all the Chaetognatha. When immersed in formalin and placed on a white background the body is very indistinctly seen, appearing like a very thin piece of slightly ground glass. The head and ovaries assume a yellowish-cream color considerably more opaque than the rest of the body. The tail is likewise more opaque, especially at the tip, shading gradually into the transparency of the body. On a black background (pl. 1, fig. 1) the head, intestine, ventral ganglion, ovaries, seminal vesicles, and tip of tail assume a whitish appearance contrasting markedly with the body which, though nearly transparent, presents a slight tinge of grayish-slate. From tip of tail the white gradually shades into the black of the body. The outlines of the fins are barely visible.

Characters

Body tumid, retaining its form well. A distinct neck separates head from body. Body much the widest at a point from 40 to 50 per cent of total length from head. Lateral fields large. Muscles weak and thin, being barely perceptible under a hand lens. Pronounced constriction at tail-septum. Collarette absent.

Anterior fin never extends to ventral ganglion. Distance from fin to ganglion usually about 20 per cent, but varies from 17 to 26 per cent. Position of greatest width always behind center of fin, varying from 63 to 73 per cent of its own length. Triangular in form with apex directed anteriorly.

Posterior fin longer and broader than anterior fin. Never extends caudally much more than half the distance from tail-septum to seminal vesicles. Never less than 50 per cent of fin in front of tail-septum, varying from 57 to 70 per cent. Position of greatest width almost uniformly opposite tail-septum. Interval from anterior to posterior fin

usually about 10 per cent, but varies from 9 to 15 per cent. Interval always less than length of posterior fin.

Vestibular ridge (pl. 3, fig. 14) provided with low rounded papillae having the appearance of a number of irregular semicircles. Number of papillae usually the same as number of posterior teeth. Two teeth (sometimes one) project beyond wing of ridge, the third (or second) barely reaching the wing. Notch covers the first three or four teeth. External process from one-half to one-third the length of ridge. It is blunt and narrow, its length being about ten times its width.

Anterior teeth, 5 to 8. *Posterior teeth,* 8 to 12, somewhat higher and broader than corresponding anterior teeth.

Seizing jaws (pl. 4, fig. 26), 8 to 9 in number. Curvature of jaw about 55 per cent. Point with an oval base and imbedded from 24 to 27 per cent of its height into shaft. Near its base the edge of point is notched. Base of point and top of shaft converge in approaching edge of jaw. Pulp-canal displaced slightly toward back of jaw. Pulp evenly distributed throughout canal.

Corona ciliata (pl. 7, fig. 45), short and almost entirely on head. It was characteristically absent in most of the San Diego material. According to Fowler (1906) it varies from a "simple sinuous outline to a complex hour glass shape." The same variation has also been noted by Ritter-Záhony (1909b).

TABLE 1

Measurements of *Sagitta enflata*[1]

Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	Anterior fin				Posterior fin			Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
					Length	Width	To ventral ganglion	To posterior fin	Length	Width	Tail-septum[2]			
1	15	12	18	74	8.9	1.9	17	10	15	3.9	62.5	7–6	10–9	9–9
2	16.5	12	17	67	13.8	2.4	19	15	17	1.7	57	7–8	10–8	9–8
3	16	8	17	68	12.5	1.5	18	11	16	3.8	63	6–6	11–11	9–9
4	18	9	17	69	8.2	1.3	23	10	16	3.9	61	7–7	10–11	9–9
5	15	6	18	70	12.0	1.4	19	10	17	4.1	63	6–?	9–9	9–9
6	17	8	18	66	11.1	2.7	17	14	16	4.0	61	6–6	11–11	9–9
7	17	9	18	66	9.3	1.5	18	9	17	4.5	60	6–6	11–10	9–9
8	19	11	21	76	13.6	2.3	21	11	15	5.3	59	7–7	11–11	8–9
9	17	11	18	72	9.4	1.4	19	10	18	4.0	66	7–7	11–11	9–9
10	16	10	16	68	13.8	1.6	20	13	16	3.9	70	7–7	11–11	9–9
11	12	8	16	68	12.8	1.6	20	11	17	3.7	59	6–6	9–9	8–9
12	17	11	22	66	13.4	2.2	26	11	21	5.7	62	6–7	11–12	8–9
13	8	8	19	73	9.0	1.5	21	8	18	4.5	59	?–?	?–?	8–6
14	10	9	20	63	12.9	2.4	17	10	17	4.9	59	?–?	?–?	?–8
15	21	9	17	70	8.6	1.2	25	11	15	3.0	63	7–?	12–10	9–8
16	20	10	15	70	7.4	1.0	26	14	15	4.1	65	6–5	11–11	9–9
17	20	10	18	71	15.9	2.8	16	8	17	5.3	69	?–?	10–10	9–8
18	10	7	24	67	10.6	2.0	20	16	12	2.6	61	4–4	8–7	9–9
19	20	11	17	70	12.3	1.0	20	11	17	4.4	61	?–?	?–?	?–?
20	18	8	18	71	10.7	1.4	29	11	18	4.4	60	6–5	10–9	9–9

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

The table above shows more accurately the measurable taxonomic features of this species. In nos. 1 and 2 the width appears as 12 per cent, but is probably incorrect owing to pressure of the cover glass. Also in no. 2 the posterior fin was so torn that the width appears too small. Again no. 5 was wrinkled so as to make the width appear too small.

In comparing this table with that of Fowler (1906) we notice several interesting differences. The number of anterior teeth averages less than he has obtained, the variation he found being from 6 to 10, while the San Diego material varies only from 4 to 8. The usual number he found to be 8, while we have found but one instance of 8, the usual number being 7. We never found an individual with more than 8, while Fowler (1906) records some twenty per cent having 10. Again, in the number of posterior teeth, Fowler (1906) finds a variation often to 17, while the San Diego specimens vary only from 6 to 12, the usual number being 10 or 11. Rarely the number drops as low as 5.

Sagitta enflata, at first sight, very strikingly resembles *S. pulchra, S. hexaptera,* and *S. lyra.* This is especially true if the specimens are not well preserved. It is, however, readily separable from *S. hexaptera* by the tooth-formula, and especially the structure of the vestibular ridge. It differs from *S. lyra* by not having confluent anterior and posterior fins, and from *S. pulchra* by absence of the collarette.

Sagitta hexaptera d'Orbigny

Pl. 1, fig. 2; pl. 3, fig. 15; pl. 4, figs. 27, 28; pl. 6, fig. 44.

Sagitta hexaptera d'Orbigny (1843), p. 140; Darwin (1844), p. 2; Hertwig (1880), p. 196; Grassi (1883), p. 10; Krumbach (1903), pp. 633, 634; Fowler (1906), p. 11; Ritter-Záhony (1908), p. 9, (1909b), p. 8.

Sagitta bipunctata, Krohn (1884), p. 108; Gegenbaur (1856), p. 14; Langerhans (1880), p. 135.

Sagitta tricuspidata Kent (1870), p. 268.

Sagitta magna Langerhans (1880), p. 135; Grassi (1883), p. 11.

Sagitta darwini Grassi (1883), p. 19.

General Appearance

This species may be recognized as one of the largest of the Chaetognatha, sometimes reaching a length of 70 mm. When placed upon a black background *S. hexaptera* presents a very

translucent, nearly transparent appearance. The general color of the body is grayish-white while the tip of the tail, ovaries, intestine, ventral ganglion, and head are much more opaque (pl. 1, fig. 2). When well-developed the seminal vesicles also offer a decided contrast to the body proper. The fins are readily seen, appearing as very transparent areas.

Characters

Body tumid, but not always retaining its form. Neck fairly evident though not so pronounced as in *S. enflata*. Body widest at a point from 35 to 45 per cent of the total length behind the head. Lateral fields large. Muscles weak and thin, but stronger than in *S. enflata*. They are barely perceptible to the naked eye. Slight constriction at tail-septum. Collarette absent.

Anterior fin shorter and narrower than posterior fin. Never extends to ventral ganglion, the distance from the ganglion being at least equal to the length of the fin. Position of greatest width approximately central. Form of fin half-elliptical.

Posterior fin always extends more than half the distance from tail-septum to seminal vesicles, but never reaches them. More than 50 (usually about 60) per cent of fin in front of tail-septum. Position of greatest width almost uniformly opposite tail-septum. Broadly triangular in form. Interval from anterior to posterior fin usually less than the length of anterior fin.

Vestibuar ridge (pl. 3, fig. 15) without the usual skeletal structures and composed entirely of a few irregular conical papillae. They apparently alternate in position with the few teeth that may be present. They are broader and much shorter than the teeth. Sometimes there is a double row of papillae present, presumably in the older individuals.

Anterior teeth usually 3 in number, varying from 2 to 4. They are long, slender, and diverging distally. The appearance of the anterior teeth, together with the skeletal areas upon which they rest, as two pronounced triangular spaces, offers an almost certain criterion for the identification of this species with the unaided eye.

Posterior teeth 2 to 4, rarely 5 in number. I have never found a specimen with more than 5, and but one with that number. Similar to anterior teeth in form but usually longer.

Seizing jaws (pl. 4, figs. 27, 28) 6 to 9 in number. Curvature about 75 per cent. Points with oval base, and imbedded from 25 to 30 per cent of their height into shaft. Tip of point blunt. Shaft below point, in most instances, provided with a short, massive crest which extends proximally for a short distance on a line with the edge of the point, and then makes an abrupt turn inward toward the shaft. Pulp-canal displaced slightly toward the back of shaft. Pulp evenly distributed and extending into the point from 55 to 66 per cent of its height.

TABLE 2

Measurements of *Sagitta hexaptera*[1]

Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	Anterior fin				Posterior fin			Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
					Length	Width	To ventral ganglion	To posterior fin	Length	Width	Tail-septum[2]			
1	27	11.0	26.8	68.8	9.8	3.6	9.2	8.2	22.2	7.0	62.5	3–3	4–4	9–9
2	24	10.0	24.1	65.0	8.6	1.7	12.2	7.9	19.9	4.1	59.7	3–3	2–2	9–9
3	55	7.3	19.0	71.5	11.8	2.7	18.5	9.3	20.0	5.2	66.2	?–?	3–2	6–5
4	40	8.3	23.0	69.0	10.7	2.5	11.5	8.6	23.0	4.9	64.1	3–3	4–3	8–8
5	22	9.0	22.2	71.0	9.0	2.4	12.0	9.0	21.0	4.5	57.0	3–2	4–4	8–9
6	52	7.6	22.0	69.5	9.9	2.5	14.8	10.8	19.5	5.3	59.0	?–?	3–2	7–6
7	52	8.0	21.0	72.0	11.5	2.8	17.0	9.0	21.0	5.6	65.3	?–3	?–2	6–5
8	41	9.7	21.3	69.0	10.1	2.1	15.0	9.5	22.0	6.0	61.2	3–3	4–4	6–?

[1] All measurements made in per cent of total length of animal.
[2] Per cent of posterior fin in front of tail-septum.

Sagitta hexaptera in general resembles *S. enflata,* and more especially *S. lyra.* It differs, however, from the former by its greater size, tooth-formula, and various proportional measurements. From the latter it differs radically in the absence of confluence of anterior and posterior fins, and in nearly all proportional measurements. Practically the only similarity between the two species consists of size, degree of transparency, and tooth-formula, the latter being often identical.

Sagitta lyra Krohn

Pl. 1, fig. 3; pl. 3, fig. 16; pl. 4, fig. 29; pl. 6, fig. 43.

Sagitta lyra Krohn (1853), p. 272; Hertwig (1880), p. 61; Grassi (1883), p. 11; Ritter-Záhony (1908), p. 10.
Sagitta hexaptera Strodtmann (1892), p. 10; Moltschanoff (1907), p. 209.
Sagitta furcata Steinhaus (1896), p. 26; Krumbach (1903), p. 630; Fowler (1905), p. 63.
Sagitta whartoni Fowler (1896), p. 992; Günther (1903), p. 336.
Spadella maxima Conant (1896), p. 212.
Sagitta gigantea Broch (1906), p. 146.
Sagitta maxima, Ritter-Záhony (1910), p. 264.

General Appearance

When well-preserved *S. lyra* appears translucent, nearly transparent upon a black background (pl. 1, fig. 3). The general color of the body is grayish-slate, the ovaries and intestines

appearing more opaque. Tip of tail and especially the head and ventral ganglion are much more opaque, presenting a distinct contrast to the body proper. Tail fin and lateral fins are readily seen with the naked eye.

Characters

Body tumid, but does not always retain its form well. It is of much the same consistency as *S. hexaptera.* Neck fairly well marked but not so pronounced as in *S. hexaptera.* Body widest at a point from 50 to 60 per cent behind the head, usually corresponding in position with the widest portion of the anterior fin. Lateral fields large. Muscles rather weak and thin, as in *S. hexaptera.* Slight constriction at tail-septum. Collarette absent.

Anterior fin longer and narrower than posterior fin. Always extends anteriorly nearly to the ventral ganglion, sometimes reaching beyond the middle of that structure. Form subject to considerable variation, but usually, in the San Diego specimens, an elongated acute triangle. It is confluent with the posterior fin.

Posterior fin extends caudally to seminal vesicles, when the latter are tumid. Never less than 50 per cent of fin in front of tail-septum. Position of greatest width is exceedingly variable, but is usually at or in front of tail-septum. Semi-elliptical in form. Interval from anterior to posterior fin is marked by the presence of a fin-bridge that renders the two fins confluent. Width at narrowest part of bridge about 1 per cent.

Vestibular ridge (pl. 3, fig. 16) consists entirely of papillae of the same style as in *S. hexaptera.* They are high, rounded, and roughly semicircular in form being, in many cases, provided with a tooth-like projection (barb) at the apex. They are more numerous than the posterior teeth, extending from beyond the external tooth to the near vicinity of the mouth. The nature of the ridge is better shown in the accompanying table.

TABLE 3

Measurements of Vestibular Ridge of *Sagitta lyra.*

Number of specimen	Length of specimen in mm.	Number of teeth	Number of papillae			Extent of ridge in Microns			Extent of tooth-row in Microns	Remarks (See pl. 3, fig. 16)
			Total	External to teeth	Internal to teeth	Total	From internal tooth	From external tooth		
1	40	4	12	3	5	909	585	169	154	Right ridge, papilla 3 and 6 with barbs
1	40	4	12	3	5	846	523	154	169	Left ridge, papilla 1 and 2 with barbs
2	33	4	14	3	5	831	477	169	184	Right ridge, papillae acutely tipped, no barbs
3	37	3	12	3	6	800	538	154	108	Right ridge, papillae acutely tipped, no barbs
4	37	4	11	2	5	800	462	154	184	Right ridge, papillae acutely tipped, no barbs
4	37	4	11	2	5	724	432	108	184	Left ridge, papillae acutely tipped, no barbs

Anterior teeth 3 to 7, closely set, conical, and converging distally. *Posterior teeth* 3 to 8, seldom closely set, and usually shorter than anterior teeth. There is considerable evidence that tends to show that the older specimens very frequently lose their teeth.

Seizing jaws (pl. 4, fig. 29) 4 to 8. Curvature about 57 per cent. Points very blunt, with oval base, and imbedded about 25 per cent of their height into shaft. Back of point has greater curvature than back of shaft, but edge of point and edge of shaft have the same curvature, so that apex of point lies nearer edge of jaw. Near its base the point makes an acute angle with both back and edge of shaft. Base of point and top of shaft converge in approaching back of jaw. Pulp-canal slightly displaced toward back of shaft. Pulp evenly distributed throughout canal, extending into the point from 52 to 64 per cent of its height.

TABLE 4

Measurements of *Sagitta lyra*[1]

Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	Anterior fin		Width of fin-bridge[2]	Posterior fin			Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
					Length[2]	Width		Length[2]	Width	Tail-septum[3]			
1	48	7.6	22.9	67.4	39.5	2.9	1.5	14.7	4.7	55.4	4–4	4–4	4–4
2	40	6.3	15.9	73.0	36.1	2.5	0.6	19.0	4.3	83.4	7–7	?–10	8–7
3	30	7.5	24.5	70.8	34.4	2.8	1.4	18.9	4.7	57.5	5–5	5–5	6–6
4	40	6.7	15.6	70.4	31.4	2.6	0.4	20.4	4.1	81.9	6–6	8–8	9–9
5	30	7.3	22.8	69.5	37.0	3.7	1.4	19.2	5.2	54.8	7–7	?–6	5–6
6	18	10.1	17.8	71.3	34.9	3.1	0.8	20.2	3.9	76.9	4–?	?–10	8–8
7	20	8.4	17.6	73.2	34.5	2.8	0.7	25.4	4.9	77.8	4–4	6–8	9–8
8	30	8.7	23.4	69.0	36.6	3.8	0.9	15.1	4.7	69.5	4–4	4–4	7–5
9	35	8.5	16.2	76.6	34.3	2.8	0.4	25.0	4.8	80.6	5–6	8–6	8–8
10	24	8.1	18.8	69.4	32.5	2.5	0.6	22.4	3.8	80.6	5–5	7–7	8–8
11	44	8.6	27.6	61.0	44.5	3.1	1.0	16.6	5.2	53.1	?–?	3–3	4–4
12	33	8.4	16.0	73.5	38.0	2.8	0.8	25.2	4.4	81.0	?–?	7–9	?–?
13	30	10.4	22.2	73.3	37.8	3.6	0.4	20.9	4.9	53.2	?–?	4–4	6–6
14	30	10.5	23.8	66.5	34.2	3.8	1.4	21.4	6.2	51.1	?–?	3–4	4–4
15	20	7.1	17.7	71.4	32.2	2.1	0.7	25.0	3.6	71.4	?–?	?–?	?–?
16	33	9.0	16.6	77.5	32.6	3.7	0.6	29.0	4.9	83.1	6–6	7–?	?–?
17	36	10.3	26.1	73.6	36.8	3.9	1.1	19.9	6.2	59.3	4–4	?–?	?–4
18	24	10.0	22.2	73.0	36.1	2.8	1.1	19.5	5.6	53.2	?–3	3–4	5–5
19	40	10.3	24.8	76.0	42.2	2.7	0.7	21.6	5.1	54.6	4–4	4–4	4–4

[1] All measurements made in per cent of total length of animal.

[2] The length of the anterior fin is measured from its most anterior extremity to the narrowest point of the fin-bridge. The posterior fin is measured from the same point, and the width of the bridge is taken at its narrowest point. The distance from anterior fin to ventral ganglion in every case has been zero.

[3] Per cent of posterior fin in front of tail-septum.

In comparing *S. lyra* from San Diego with Fowler's (1905) description and figures of *S. furcata,* one can not fail to see a great resemblance, brought out especially in his plate 4, figures 9 and 10. Furthermore the structure of the seizing jaws described by Krumbach (1903) for *S. furcata,* tallies except in two points, with the jaws in *S. lyra* from this region. The two exceptions consist, first in the absence in *S. lyra* of the cucumber-shaped area near the base of the shaft in which the pulp is absent from the canal, and, second, in the fact that the point, near its base, makes an angle with edge and back of shaft.

Twice Fowler has been on the point of asserting identity between the two species. In his report on Biscayan Plankton (1905, p. 64) he says of *S. lyra*: "*Krohn very likely had furcata before him.*" Later, in the Siboga Report (1906, p. 33) he says: "A few specimens with this label [*S. lyra* Krohn] were received from the Zoological Station in Naples. *I still think that this species is probably furcata Steinhaus. . . . But on spirit material it is impossible to feel positive on this point.*" [Italics mine.]

Finally, through the excellent work of Ritter-Záhony (1908) there is practically no doubt left as to the identity of these two species. He finds that *S. furcata* is really a younger stage in the development of *S. lyra.*

In comparing *S. lyra* from San Diego with the description of *S. whartoni,* the similarity of the two species is very striking. Below are given measurements of *S. whartoni* taken from Fowler's (1896) original description and drawings.

TABLE 5

Measurements of *S. whartoni*

(All measurements made in per cent of total length of animal.)

Length in mm.	Width	Length of tail	Anterior fin		Posterior fin		Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
			Length	Width	Length	Width			
30–45	6.6–10.5	20–26	44–66	2.8	19–33	5.7	3–5	5–7	8–10

In comparing these measurements with those just given for *S. lyra,* the only differences consist in the greater length of anterior and posterior fins. San Diego material has yielded no

specimens with a length of more than 44.5 per cent for the anterior, nor more than 29 per cent for the posterior fin.

Fowler (1896, p. 992) recognized this similarity to *S. lyra* but defined differences on the ground of number of teeth and seizing jaws, and of the absence of a constriction at the tail-septum in *S. whartoni.* In the San Diego *S. lyra* the constriction at the tail-septum varies, and in many instances is practically absent, and the number of teeth and seizing jaws are essentially the same as in Fowler's *S. whartoni,* as shown by comparison of tables 4 and 5. It is to be regretted that Fowler (1896) did not describe the vestibular ridge. However, from the data at hand, it seems only reasonable to regard *S. whartoni* as a synonym of *S. lyra.*

Through the courtesy of Dr. Broch of the University of Christiania, I have been enabled to work over three of his specimens of *S. gigantea,* the measurements of which are as follows:

TABLE 6

Measurements of *S. gigantea*[1]

Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	Anterior fin			Width of fin-bridge	Posterior fin			Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
					To ventral ganglion	Length	Width		Length	Width	Tail-septum[2]			
1	78	6.4	22	70.6	0	42.3	2.6	1.3	16.7	3.8	61.5	?–?	4–?	4–4
2	56	7.1	23.2	69.6	0	42.0	3.6	1.8	14.3	4.4	62.5	5–4	6–4	7–6
3	69	5.8	23.2	72.0	0	39.8	2.9	1.4	16.7	4.3	61.0	6–5	5–5	6–6

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

In no. 1 the posterior fin is widest at tail-septum, and does not quite reach the seminal vesicles. In nos. 2 and 3 the fin is widest behind tail-septum and the seminal vesicles are not developed.

Comparison of this material with *S. lyra* from San Diego presents only a very few differences. Broch's specimens are larger, the smallest measuring some 4 mm. more than the largest S. lyra from this region. In one instance the width of *S. gigantea* is only 5.8 per cent, while none of our specimens measure less than 6.3 per cent. With these two exceptions all the measurements of *S. gigantea* agree with those of *S. lyra.*

Furthermore, the nature of the vestibular ridge (pl. 3, figs. 16, 17), while totally different from nearly all other species, is precisely the same in the two forms.

Broch (1906) says that *S. gigantea* seems to resemble *S. whartoni* but differs in size, smaller number of seizing jaws, and larger number of teeth. Fowler (1896) records 3 to 5 as the variation in number of anterior teeth of *S. whartoni.* In two of the three specimens of *S. gigantea* considered in table 6, the teeth are 5-4 and 6-5, a difference of only one tooth from the number reported by Fowler (1896). Broch (1906) finds from 7 to 8 posterior teeth but, in the above specimens, I have been unable to discover more than 6. Even if 8 were frequently present there would be only one more tooth than is recorded by Fowler (1896) for *S. whartoni.* Again, some of the San Diego specimens of *S. lyra* bear 9 seizing jaws on each side of the head which otherwise agree perfectly with *S. gigantea,* except in their smaller size. With such similarity the identity of *S. gigantea* with *S. lyra* seems quite evident.

Through the courtesy of the United States National Museum I have had the privilege of examining three specimens of *Spadella maxima* Conant. That they are identical with the San Diego material there is not the slightest doubt. In fact the agreement is so close that I am unable to detect any differences except that in *S. maxima* the vestibular papillae are more uniformly provided with barbs than is true of the *S. lyra* from San Diego.

Through a letter received from Dr. Rudolph von Ritter-Záhony I find that he agrees with me in regarding *S. whartoni, S. gigantea,* and *S. maxima* as synonyms (see also Ritter-Záhony, 1910, p. 264), but fails to understand how I can identify them with *S. lyra.* He says: "Ich begreife nicht wie Sie die Species [*S. lyra*] mit *S. whartoni,* und *S. gigantea* vereinigen können, da aus dem Beschreibungen Fowler's und Broch's sich ja schon bedeutende Unterschiede ergeben." The only differences mentioned in these two papers by Fowler (1896) and Broch (1906) have already been considered sufficiently to indicate that the differences are not so significant as might at first appear. Furthermore, I have sent three of

the San Diego specimens of *S. lyra* to Ritter-Záhony for corroborative identification and I take the liberty to quote his reply. He says: "Sie haben sie ganz richtig als *S. lyra* bestimmt, es kann darüber gar kein Zweifel sein." I am therefore quite positive that my specimens are referable to *S. lyra* and if so I can detect no appreciable difference between them and *S. gigantea* or *S. maxima.* It is possible that I may have obtained both *S. lyra* and *S. maxima* and confused them, but such an error is improbable.

S. lyra also bears a striking resemblance to *S. gazelle.* In regard to the latter species Ritter-Záhony (1909c, p. 788) says: "Durch die Gestalt der Vestibularorgane und *die ausserordentliche relative Kürze des Schwanzabschnittes* [italics mine] ist diese Art so gut gekennzeichnet dass die Identifizierung späterhin mit Sicherheit möglich sein wird." Nevertheless this species bears a striking resemblance to our specimens of *S. lyra.* While in *S. gazelle* Ritter-Záhony (1909c) records the tail per cent as 10 to 14, with one possible instance of 19, the San Diego *S. lyra* shows a variation as low as 15.6 per cent, a difference of only 1.6 per cent from his measurements of *S. gazelle.* From his tabulation for *S. lyra* (1908, p. 12) in specimens of 27 mm. in length he records 4 mm. as the tail length, which amounts to 14.8 per cent, but he describes the tail as 17 to 23 per cent. From his tabulations it frequently falls below 16 per cent, which means that there is an error somewhere in his data. Surely the difference between *S. lyra* and *S. gazelle* in this matter of the length of tail is not great. The vestibular ridge, again, is amazingly similar to that of *S. lyra,* and the nature of the posterior teeth in *S. gazelle* that Ritter-Záhony (1909c, p. 788) describes as "aneinanderschliessend (d.h. nicht durch Zwischenräume getrennt wie bei manchen Arten)" is essentially the same in San Diego specimens of *S. lyra* possessing 7 to 10 teeth. On the other hand, the mature ovary in *S. lyra* (see p. 59, tab. 18, and pl. 6, fig. 43) extends nearly, if not quite to the ventral ganglion, whereas in *S. gazelle* Ritter-Záhony (1909c, p. 788) says: "Die Ovarien machten trotz ihrer Kürze bei einigen Individuen schon den Eindruck der Reife." Inasmuch as a figure of *S. gazelle* has not been published and

as the fins were too damaged for description, it seems best to have it remain a valid species until redescription is possible.

Sagitta serratodentata Krohn

Pl. 1, fig. 4; pl. 3, fig. 20; pl. 4, fig. 30; pl. 5, fig. 41.

Sagitta serratodentata Krohn (1853), fig. 2; Hertwig (1880), p. 64; Strodtmann (1892), p. 17; Krumbach (1903), p. 636; Fowler (1905), p. 58; Ritter-Záhony (1908), p. 15 (1909b), p. 8.
Sagitta sp. innom., Gegenbaur (1856), p. 15.
Sagitta gegenbauri Fol (1879), p. 123.

General Appearance

This slender, pin-shaped species, when placed upon a black background, appears very opaque (pl. 1, fig. 4). The head, ventral ganglion, intestine, and seminal vesicles are readily distinguished as slightly more opaque than the body proper. The seminal vesicles, when fully ripe, stand out clearly as extremely opaque areas. The tail is slightly more transparent than the body. The tail-fin and both pairs of lateral fins, in perfectly preserved material, are barely visible to the naked eye, appearing as nearly transparent areas. The ovaries, owing to the opacity of the body, are very indistinctly seen. It is to be noted that, when sexually mature (pl. 5, fig. 41) *S. serratodentata* presents a much greater opacity, owing probably to the greater length and opacity of the ovaries. When not mature this species is slightly less opaque than *S. planktonis,* but when fully developed it is more opaque.

Characters

Body firm and rigid, retaining its form well. Neck very prominent. Body widest at about middle of length, varying from 50 to 55 per cent, and tapering very gradually toward head and tail. Lateral fields small. Muscles broad and strong. No constriction at tail-septum. Collarette absent.

Anterior fin shorter and somewhat narrower than posterior fin. Extends to ventral ganglion. Position of greatest width well toward posterior end. Form approximately triangular.

Posterior fin extends caudally to seminal vesicles when they are tumid. In exception to all the other San Diego species, the proportion of posterior fin in front of tail-septum is exceedingly variable, there being sometimes more and sometimes less than 50 per cent. Position of greatest width well behind septum, usually at a point about half the distance to seminal vesicles. Interval from anterior to posterior fin small.

Vestibular ridge (pl. 3, fig. 20) well developed, as long as posterior

row of teeth and provided with low, rounded papillae, each one approximately representing the quadrant of a circle. They are fewer in number than posterior teeth. Three or four teeth project beyond wing of ridge, the notch extending to the sixth or seventh tooth. External process one-fourth to one-fifth the length of entire ridge. It is from two to three times broader at end than at wing.

Anterior teeth, 6 to 9 in number. They are conical, closely set, and slightly diverging distally. *Posterior teeth,* 13 to 19 in number. Similar in form to anterior teeth, but apparently shorter and broader. They are very closely set.

Seizing jaws (pl. 4, fig. 30), according to Fowler (1905), vary from 6 to 8 in number. In the San Diego specimens the number varies from 5 to 7. Curvature about 54 per cent. Shaft usually conspicuously serrated, the serrations, gradually and somewhat irregularly, increasing in size proximally, and disappearing entirely somewhat above middle of jaw. Point curved toward edge of jaw presenting the variation that Krumbach (1903) demonstrated. Point imbedded about 25 per cent of its height into shaft. Top of shaft and base of point parallel. Pulp evenly distributed throughout canal, the latter being slightly displaced toward back of jaw.

TABLE 7

Measurements of *Sagitta serratodentata*[1]

Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	Anterior fin			Posterior fin		Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
					To ventral ganglion	Length	To posterior fin	Length	Tail-septum[2]			
1	14.0	6.5	28.0	66.0	0	22.0	4.4	27.5	41.0	8–9	18–19	6–6
2	13.0	5.7	26.0	67.0	0	20.0	9.1	27.0	44.0	8–7	17–17	6–6
3	16.0	5.6	22.0	58.6	0	12.5	11.5	18.3	44.5	7–8	16–16	6–6
4	13.0	5.3	26.1	80.0	0	27.8	7.7	30.0	62.6	9–8	16–17	6–6
5	11.4	4.8	25.2	73.0	0	27.1	2.4	29.0	57.5	7–7	14–14	6–6
6	14.0	6.2	28.0	68.5	0	25.0	3.8	27.0	46.0	8–7	14–13	5–5
7	14.3	4.5	22.8	63.2	0	18.2	4.2	29.0	62.4	7–6	13–13	7–6
8	10.0	5.4	27.2	56.0	0	16.3	5.4	25.0	56.5	6–7	14–14	6–6
9	15.3	4.6	22.7	69.0	0	19.8	5.3	22.0	51.5	8–8	16–17	6–?
10	14.5	3.4	26.1	69.0	0	20.4	10.0	22.4	50.0	6–6	14–15	5–5
11	15.4	3.9	23.0	70.5	0	23.0	12.4	24.8	57.1	7–7	16–15	7–7
12	12.7	4.3	23.5	72.5	0	23.5	11.9	25.6	50.0	8–7	16–17	6–6
13	12.7	3.8	26.0	70.0	0	21.3	7.2	22.6	58.5	?–?	?–?	?–?
14	14.4	4.5	21.8	61.4	0	23.3	4.9	24.5	61.5	7–?	16–?	6–?
15	17.1	5.1	22.1	63.0	0	20.6	6.3	25.3	62.5	6–6	15–15	6–6

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

The action of formalin causes the lateral fields to shrink inward, with the result that the fins are nearly hidden from view. As a consequence, width-measurements of the fins could not be made with any accuracy except in the first two specimens, which were measured directly after preservation. In no. 1 width of anterior fin was 3.5 per cent, posterior fin 6.2 per cent. In no. 2 the widths were 3.0 and 6.0 per cent.

In comparing the San Diego specimens with those which Fowler (1905) obtained, we notice a great difference in number of anterior and posterior teeth. He records from 3 to 7 anterior and 3 to 13 posterior teeth in individuals ranging from 5 to 15 mm. in length. For a length of 13-14 mm. he finds 5 to 7 anterior and 8 to 12 posterior teeth. The specimens from San Diego, therefore, present a greater number of teeth for the same length of individual.

Sagitta bipunctata Quoy et Gaimard

Pl. 1, fig. 5; pl. 3, figs. 18, 19; pl. 4, figs. 31, 32; pl. 5, fig. 40.

Sagitta bipunctata Quoy et Gaimard (1827), p. 232; Busk (1856), p. 16; Hertwig (1880), p. 258; Strodtmann (1892), p. 344; Fowler (1905), p. 69, (1906), p. 31; Ritter-Záhony (1908), p. 15.
Sagitta sp. innom., Oersted (1849), p. 26.
Sagitta multidentata Krohn (1853), p. 271.
Sagitta germanica Leuckart und Pagenstecher (1858), p. 593; Uljanin (1871), p. 77.
Sagitta setosa Keferstein (1862), p. 135.
Spadella bipunctata, Grassi (1883), p. 13.
Spadella mariona Gourret (1884), p. 103.
Spadella hamata, Aurivillius (1898), p. 117.
Sagitta decipiens, Michael (1908), p. 68.
Sagitta pulchra, Michael (1908), p. 68.
Sagitta bipunctata forma typica Ritter-Záhony (1910), p. 255.

General Appearance

This species is only slightly more opaque than *S. enflata,* but appears to the naked eye somewhat narrower, more rigid, and of more uniform width from head to tail. When on a black background (pl. 1, fig. 5) the head, intestine, ventral ganglion, ovaries, seminal vesicles, and tail present a distinct, though rather less, contrast to the body proper than is the case with *S. enflata.*

Characters

Body rigid, retaining its form well. Neck nearly, if not quite absent. Body widest usually behind middle, but varies from 40 to 60 per cent. It tapers very gradually forward and backward from this point. Lateral fields large. Muscles thin and weak but stronger than those of *S. enflata,* the strands being barely visible under a dissecting lens. Constriction at tail-septum evident. Collarette present but very short.

Anterior fin never extends forward to ventral ganglion. Interval between fin and ganglion usually about 7 per cent, but varies from 4 to 10 per cent. Fin rather triangular in form.

Posterior fin longer and broader than anterior fin, extending to seminal vesicles when latter are tumid. Always more than 50 per cent of fin in front of tail-septum. Interval from anterior to posterior fin varies from 4 to 11 per cent, but is usually 6 or 7 per cent, and is never over half the length of posterior fin.

Vestibular ridge (pl. 3, fig. 18) provided with low, blunt papillae considerably irregular in form. Usually one papilla for every posterior tooth. Ridge covers all except the last one or two teeth. External process acute, narrow, and long, being about half as long as the rest of the ridge. Certain individuals present the appearance (pl. 3, fig. 19) of a double ridge similar to that noted by Fowler (1905) in *S. decipiens,* both parts possessing acute external processes which fork apart at the point where the wing of the ridge descends.

Anterior teeth, 5 to 8 in number. They are closely set and conical in form. *Posterior teeth* 9 to 14, and similar, in form, to anterior teeth. They are, however, larger excepting the first and last, which may be slightly shorter.

TABLE 8

Measurements of *Sagitta bipunctata*[1]

Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	Anterior fin: To ventral ganglion	Anterior fin: Length	Anterior fin: Width	Anterior fin: To posterior fin	Posterior fin: Length	Posterior fin: Width	Posterior fin: Tail-septum[2]	Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
1	12	6	23	71	7	21.6	2.4	7	22.4	4.5	64	5–5	14–13	8–8
2	17	5	22	71	10	17.4	2.3	10	21.3	3.1	56	5–5	?–13	?–?
3	16	6	21	70	9	15.9	2.0	8	23.2	3.6	57	?–?	?–?	?–?
4	17	6	22	70	7	21.5	2.0	4	23.1	3.7	65	?–?	?–?	?–?
5	9	5	22	69	5	22.5	2.4	4	24.5	3.8	63	?–?	13–?	8–?
6	16	6	21	70	5	22.5	2.3	8	24.9	3.8	62	6–7	13–14	8–8
7	16	6	24	70	8	20.6	2.0	7	24.2	3.3	58	?–?	13–13	?–?
8	17	6	24	70	6	20.0	2.5	6	23.4	3.9	50	6–6	13–13	7–8
9	17	7	25	73	6	20.4	1.6	7	26.5	4.1	60	5–5	12–?	?–?
10	14	6	22	70	8	20.2	1.4	9	21.6	3.8	53	6–5	12–?	8–?
11	15	6	24	71	7	22.4	1.8	6	23.5	4.1	62	?–6	?–12	?–?
12	16	6	23	69	7	18.6	1.7	8	22.1	3.8	56	?–?	12–?	8–8
13	17	5	24	69	5	20.0	2.1	6	25.3	4.3	58	?–6	?–13	8–8
14	16	6	23	71	8	19.9	1.7	6	23.3	3.6	58	?–?	?–?	8–8
15	15	6	23	71	5	20.8	2.2	4	24.9	3.9	60	5–5	13–?	8–8
16	17	6	23	71	8	18.9	2.0	7	26.2	4.0	57	?–?	?–?	?–?
17	15	5	23	70	5	20.4	2.2	7	24.8	3.9	60	5–5	13–13	7–8
18	16	6	23	70	5	20.5	2.1	7	25.1	4.2	58	5–5	13–12	8–8
19	15	6	24	72	5	23.7	2.3	6	26.4	4.1	60	5–5	13–?	?–8
20	14	6	22	70	5	20.9	2.3	5	23.2	4.2	60	?–?	?–?	?–?

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

Though obtained by the thousand, the head in nearly every case was extremely contracted, thereby making a correct count of the teeth almost impossible.

Seizing jaws (pl. 4, figs. 31, 32), 7 to 8 in number. Curvature about 33 per cent. Points of same general form as those described by Krumbach (1903) for *S. furcata,* the curvature along the back being greater than along the edge so that apex of point lies toward edge of jaw. Point inserted about 27 per cent of its height into shaft. Base of point and top of shaft converge on approaching edge of jaw. Pulp evenly distributed throughout canal, the latter being displaced toward back of shaft. Pulp-canal extends into the point from 66 to 75 per cent of the height of the point. Apex of canal lies very near back of point. Older jaws sometimes present a swollen place in the pulp slightly below point. The convergence of top of shaft and base of point is more marked in the older jaws.

During the summer of 1907 I had the opportunity of examining a large number of individuals of this species alive, and the characters presented forcibly remind one of Conant's (1895) description and figure of *Sagitta hispida.* Covering the body at intervals, arranged symmetrically on the two sides forming twelve longitudinal rows, are numerous tactile hairs which present a remarkably *hispid* appearance. This appearance ceases entirely when the animal is killed and preserved. The *corona ciliata* was also found to agree very closely with that figured by Conant (1895) for *S. hispida.* It is rather broad, somewhat sinuous, and roughly resembles a ten-pin in outline. It extends from in front of the eyes to a point about half way from the head to the ventral ganglion, being more on body than head.

At first I was inclined to think that *S. hispida* was a synonym for *S. bipunctata,* but careful comparison has convinced me that they are not the same species. The tail of *S. bipunctata* is proportionally too short, the posterior fins present more than 50 per cent in front of tail-septum, and the general appearance of the body is much different.

S. bipunctata bears a strong resemblance to *S. decipiens.* In fact the similarity is so great that I made (1908) the mistake of identifying my material as *S. decipiens.* The nature of the mature ovaries is much the same, and nearly all the proportional measurements overlap to a surprising extent. There are, however, a few points of difference. The tail in *S. decipiens* varies from 28 to 40 per cent, the seizing jaws are 5 to 6, the number of anterior and posterior teeth is somewhat greater, and

there is no constriction at the tail-septum. Whether or not the two species are in reality distinct I am not sure, but until I am enabled to study *S. decipiens* with care I can not feel positive concerning their relationship.

Sagitta planktonis Steinhaus

Pl. 1, fig. 6; pl. 3, fig. 21; pl. 4, fig. 33; pl. 5, fig. 42; pl. 7, fig. 46; pl. 8, fig. 48.

Sagitta planktonis Steinhaus (1896), p. 39; Ritter-Záhony (1909c), p. 790.

Sagitta zetesios Fowler (1905), p. 67, (1906), p. 22.

General Appearance

On a white background *S. planktonis* appears very opaque. The body proper assumes a light cream color, while the seizing jaws and tail present a light brown tint. The ovaries when immature are so slender and the muscles so thick that it is impossible to see the ovaries with the naked eye. Even with a microscope they are usually difficult to discern. On a black background (pl. 1, fig. 6) the animal appears nearly white, the body proper assuming a very pale bluish tint, while the head and ventral ganglion appear somewhat whiter. The tail fin and both pairs of lateral fins are readily seen with the naked eye, appearing as transparent areas in decided contrast to the general opacity of the body.

Characters

Body stout and rigid, retaining its form almost perfectly. Neck evident. Body widest behind center, at a point from 50 to 63 per cent of its length, gradually tapering toward head and tail. Lateral fields small. Muscles strong and thick. No constriction at tail-septum. Collarette present (pl. 7, fig. 46; pl. 8, fig. 48), extending posteriorly to anterior fins.

Anterior fin longer and narrower than posterior fin. It usually extends to ventral ganglion, but rarely falls short by not more than 0.1 per cent of the total length of the animal. Widest point of fin about 80 per cent of its length from anterior end. Triangular in form, with the acute apex continuous with the collarette.

Posterior fin never extends to seminal vesicles. From 55 to 72 per cent of fin in front of tail-septum. Point of greatest width in front of tail-septum. Triangular in form, the obtuse angle being on the line of greatest width. Interval from anterior to posterior fin varies from 7 to 12 per cent.

Vestibular ridge (pl. 3, fig. 21) well developed, the papillae being small and very irregular in form and position. They are not present

over the posterior half of the ridge. Wing of ridge covers all but the first tooth. In some rare instances two teeth are left exposed, and in others all the teeth are covered. External process short and thick, about one-third the length of ridge, and from two to three times longer than broad. Notch extends inward beyond the fourth and nearly to the fifth tooth.

Anterior teeth 4 to 7 in number. Closely set and increasing in size as they approach internal angle. They are narrow in proportion to their height. *Posterior teeth* 11 to 15 in number. Similar in form to anterior teeth but higher and relatively narrower.

Seizing jaws (pl. 4, fig. 33) 8 to 9, rarely 10 in number. Curvature about 12.7 per cent. Points with oval base. Tip of point rather blunt. Curvature of back greater than curvature of edge of point so that apex lies nearer edge. Point imbedded from 20 to 25 per cent of its height into shaft. Base of point and top of shaft converge in approaching back of jaw. Pulp-canal approximately central with the pulp evenly distributed.

TABLE 9

Measurements of *Sagitta planktonis*[1]

Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	Anterior fin				Posterior fin			Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
					Length	Width	To ventral ganglion	To posterior fin	Length	Width	Tail-septum[2]			
1	24	7	25	70	23.5	2.5	0	9	17.9	3.9	60	5–5	12–13	8–8
2	25	9	25	59	22.3	2.4	0	9	17.4	3.3	60	?–4	12–13	8–8
3	26	7	26	70	23.1	2.6	0	9	20.5	4.1	56	5–6	12–?	9–8
4	24	7	24	69	19.9	2.5	0	11	19.2	3.1	63	?–?	?–?	?–?
5	26	7	26	70	22.8	2.2	0	8	16.9	3.8	60	5–6	?–15	8–8
6	15	10	38	63	27.0	3.6	0	9	23.6	5.4	62	5–7	13–13	8–8
7	17	9	37	69	22.5	2.8	0	10	16.3	3.6	59	6–6	?–?	8–9
8	22	8	27	50	18.8	1.8	0	11	15.8	3.6	58	7–?	?–?	8–9
9	26	8	25	68	22.8	2.5	0	9	16.5	4.3	62	7–7	12–11	8–8
10	24	7	27	69	21.2	2.3	0	8	17.9	4.4	62	6–7	?–?	8–9
11	23	8	27	69	22.3	2.3	0	7	17.2	4.3	70	?–?	?–?	?–?
12	17	9	25	66	21.2	2.4	0	10	18.3	3.3	71	?–?	?–?	8–8
13	20	8	28	70	21.6	3.0	0	10	17.6	3.7	59	7–6	?–?	9–8

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

In my material none of the individuals was sexually mature. The ovaries were slender and the eggs small, notwithstanding the fact that the ovaries extended to the cephalic end of anterior fin. Most of the specimens show apparent transverse septa across the intestine, as described by Doncaster (1902a) for *S. minima,* and his explanation of this fact as due to the drawing apart of the walls of the intestine is evidently true in *S. planktonis.* One specimen still retained the *corona ciliata* (pl. 7, fig. 46). It is skein-shaped with more than three-fourths on head, and extending from one-third to one-half its length anterior to the eyes.

Ritter-Záhony (1909c, p. 790) says: "Zweifellos ist *S. zetesios* mit ihr [*S. planktonis*] identisch," and I think we must fully agree with him. The similarity extends to nearly every point. Fowler (1905, p. 71) records three specimens which he doubtfully identifies as *S. planktonis,* but states that "they bear a close general resemblance to *zetesios.*" He then points out the following differences: In *S. zetesius* the anterior and posterior fins are closer together, and the former extends farther forward. The widest portion of the posterior fin is level with or behind the tail-septum, the posterior fin is more on the trunk than tail, and the posterior teeth number less for the same length. In all these points the specimens from San Diego are quite variable, except that the posterior fin is more on the trunk than on the tail, which condition is the same as described by Fowler (1905) for *S. zetesios.*

S. planktonis at first sight bears a certain resemblance to *S. bedoti,* and *S. ferox.* It is however readily separable from the former by the presence of such a conspicuous collarette, and by the fact that the anterior fin is longer than the posterior one. From the latter it differs in having a greater number of seizing jaws, more than 50 per cent of the posterior fin in front of tail-septum, narrower collarette, and in many of the proportional measurements. It bears some resemblance to *S. robusta,* but the body of the latter is proportionally narrower, the collarette is less extensive, and the anterior fin is shorter than the posterior fin.

Sagitta neglecta Aida.

Pl. 2, fig. 7; pl. 3, fig. 22; pl. 4, fig. 34

Sagitta neglecta Aida (1897), p. 16; Fowler (1906), p. 15.
Sagitta bipunctata, Béraneck (1895), p. 153.

General Appearance

In degree of opacity this species bears a strong resemblance to *S. serratodentata.* It is, however, more slender and pin-shaped. Upon a black background (pl. 2, fig. 7) the head, ventral ganglion, and seminal vesicles appear more opaque than the body. The intestine and ovaries are only slightly different in opacity from the body. The entire tail segment is slightly

less opaque than the body, and the seminal vesicles do not present such decided contrast as in *S. serratodentata.* The form, with the comparatively large head and the body gradually tapering from the head to a point at the tail, reminds one very forcibly of a pin. The fins are barely visible as nearly transparent areas.

Characters

Body firm and rigid, retaining its form well. Neck very pronounced but made less conspicuous by the *collarette* which extends well toward, but never reaches the ventral ganglion. Body nearly of uniform width, but slightly wider from a point at a level with posterior end of anterior fins to a point at a level with anterior end of posterior fins. This point of greatest width varies from 52 to 60 per cent. Lateral fields small. Muscles rather broad and strong. No constriction at tail-septum.

Anterior fin shorter and narrower than posterior fin. Extends to posterior end of ventral ganglion. In form it is narrowly and acutely triangular.

Posterior fin extends nearly, if not quite to seminal vesicles when the latter are tumid. Never more than 50 per cent of fin in front of tail-septum. Widest slightly behind tail-septum. Half elliptical in form. Interval from anterior fin to posterior fin considerably less than the length of anterior fin. It varies from 8 to 16 per cent.

Vestibular ridge (pl. 3, fig. 22) with very low and regular papillae. Usually one papilla over each tooth. Wing of ridge covers all but one tooth. Rarely two teeth are exposed. External process very short, barely including the first tooth. It is three or four times longer than broad and about one-fourth the length of entire ridge.

Anterior teeth 3 to 5, closely set, and not diverging much distally. *Posterior teeth* 8 to 11, somewhat longer and proportionally narrower than anterior teeth. Like anterior teeth, they do not diverge much distally.

Seizing jaws (pl. 4, fig. 34) 7 to 9. Curvature about 53 per cent. Point resembles, in form, that described by Krumbach (1903) for *S. bipunctata.* It is, however, broader for its height and is inserted about one-fifth instead of one-fourth of its height into the shaft. Top of shaft and base of point parallel. Edge of point at intersection with top of shaft, makes an acute angle with edge of shaft. Edge of point and edge of shaft diverge proximad of this intersection. Back of point and back of shaft parallel. Pulp-canal central, with the pulp evenly distributed.

TABLE 10

Measurements of *Sagitta neglecta*[1]

Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	Anterior fin				Posterior fin			Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
					To ventral ganglion	To posterior fin	Length	Width	Length	Width	Tail-septum[2]			
1	12	5.1	26	71	0	8.7	23	2.5	26	5.0	49	3–3	10–11	8–9
2	12	5.4	26	69	0	15.6	18	1.8	20	3.0	43	4–4	9–10	8–8
3	7.9	4.3	27	68	0	11.0	20	1.4	22	2.5	40	?–?	8–8	8–8
4	11	4.2	27	69	0	11.0	21	1.6	23	3.2	47	4–5	9–9	9–8
5	12	5.3	26	69	0	13.2	19	1.6	22	2.9	45	4–4	11–10	8–7
6	10	5.0	28	73	0	10.8	19	1.6	22	2.8	49	4–4	9–8	8–7
7	8	4.2	28	69	0	10.5	19	1.4	25	3.5	48	4–4	9–8	8–8
8	11	6.0	28	70	0	9.5	20	2.2	26	3.9	48	4–4	8–8	8–8
9	13	5.4	26	68	0	11.6	20	1.5	24	3.6	45	3–3	10–10	8–8
10	12	6.3	27	69	0	11.0	20	2.1	21	3.1	44	4–4	8–8	?–?
11	10	4.9	30	70	0	11.7	19	1.8	23	3.1	40	4–3	8–8	?–?
12	13	6.4	26	68	0	11.3	21	2.2	22	3.2	44	?–?	9–9	8–8

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

In comparison with Fowler (1906) a number of differences in some of the measurements are evident. He finds the tail to vary from 26 to 37 per cent in individuals ranging from 7.5 to 10 mm. in length. In the San Diego specimens the variation is only 26 to 30 per cent. The seizing jaws we found to vary from 7 to 9, instead of from 5 to 8 in number as recorded in the "Siboga" material. Fowler (1906) records the anterior teeth as 3 to 7, the usual number, perhaps, being 6, while San Diego specimens present 5 as the greatest number. Similarly *S. neglecta* from this region are provided with fewer posterior teeth, 8 to 11 as against 9 to 15 recorded by Fowler (1906).

From Aida (1897), however, we find the variation as follows: seizing jaws 8, anterior teeth 4 to 5, posterior teeth 10 to 12. Aida (1897) describes the tail as 24.3 per cent, but draws it 35 per cent, and one is at a loss to know which expresses the truth. Nevertheless there is striking agreement between Aida's description and specimens from San Diego.

I know of no two species more perplexing to identify than *S. neglecta* and *S. regularis,* both first described by Aida (1897). He defines the following differences. Anterior fin in *S. regu-*

laris nearly half as long as posterior fin, while the fin in *S. neglecta* is very little shorter than posterior fin. The posterior fin in the latter species extends further in front of tail-septum than in *S. regularis.* Measurements taken from Aida's (1897) drawings of the two species show the following relations.

TABLE 11

Measurements taken from Aida's Drawings[1]

Species	Width	Length of tail	Anterior fin			Posterior fin			Number of anterior teeth	Number of posterior teeth	Number of seizing jaws
			Length	Width	To posterior fin	Length	Width	Tail-septum[2]			
S. neglecta	5	35	17.5	2.5	7.5	25	3.8	40	4–5	10–12	8
S. regularis	7	37	16.3	4.5	7.0	28	5.6	33	2–4	5–7	7

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

In the matter of relative lengths of anterior and posterior fins of the two species the drawings do not show much difference. The relative per cent of posterior fin in front of tail-septum has more significance, although a large number of measurements of both species are necessary in order to definitely establish any specific difference in this regard.

Fowler (1906) has defined certain other characteristics, some of which seem invalid. He claims (1906, p. 16) that in *S. neglecta* "the tail is slightly shorter" than in *S. regularis,* which he regards as one of the "*main points of difference.*" [Italics mine.] However, when his data are brought together as in the accompanying table, it is seen that for the lengths of

TABLE 12

Comparative Lengths of Tail

Length of specimen in mm.	*S. neglecta* per cent	*S. regularis* per cent
4.5		33
5.0	30–40	40
5.5	30–36	36
6.0	33	33
6.5	30	
7.0	26–35	28
7.5	26–33	
8.0	30–37	
9.5	31	
10.0	30	

5, 5.5, and 6 mm. there is perfect correspondence in the length of the tail in the two species, and in specimens 7 mm. in length *S. neglecta* actually oversteps *S. regularis.* Even if taken in their entirety, the total variation Fowler (1906) finds is 26 to 40 per cent in *S. neglecta* and 28 to 40 per cent in *S. regularis.* Certainly there is no significant difference in the tail measurements of the two species.

Fowler (1906) also finds a difference in the number of anterior and posterior teeth, as indicated in table 13.

TABLE 13

Number of Teeth according to Fowler (1906)

Common length in mm.	*Sagitta neglecta* Anterior teeth	*Sagitta neglecta* Posterior teeth	*Sagitta regularis* Anterior teeth	*Sagitta regularis* Posterior teeth
4.5			2	2
5.0	3–4	7–10	2–3	5–6
5.5	4	10–11	2	4
6.0	3–5	9–11	2–3	6
6.5	4–5	9–10		
7.0	4–6	9–12	4	6

From this table we see that the anterior teeth present a difference of only two. The difference in the posterior teeth is greater but, on account of a much larger variation in some species, notably *S. enflata* and *S. bipunctata,* it is impossible to feel sure that this difference signifies anything beyond individual variation.

Fowler (1906) regards the *corona ciliata* as longer in *S. neglecta* and extending for some little distance onto the head. In *S. regularis* he finds it is entirely confined to the body. In certain instances, however, he finds the *corona of S. neglecta* confined to the body, and in his drawing (1906, pl. 1, figs. 43, 44) he represents two lengths of the structure. One would desire to know the variation in length and exact position of this structure before placing much confidence in this criterion for separating two such closely allied forms.

Finally, it was pointed out that the collarette is much wider and longer in *S. regularis,* extending to the anterior fins as in *S. planktonis.* In no instance was this true of the San Diego specimens of *S. neglecta.*

Apparently, we have but two fairly sure characters for distinguishing between *S. neglecta* and *S. regularis.* One consists in the per cent of posterior fin in front of tail-septum, which is 33 in *S. regularis* and never less than 38 in *S. neglecta.* The other point of difference consists in the width, and especially the length of collarette as defined above. Perhaps we have here the explanation of the more uniform width of body in *S. regularis.*

S. neglecta also bears considerable resemblance to *S. bipunctata.* The following differences, however, exist. In the latter species the anterior fins never reach the ventral ganglion, there is more instead of less than 50 per cent of posterior fin in front of tail-septum, and the general appearance is much more transparent.

Genus **Eukrohnia** Ritter-Záhony

Syn. *Krohnia* Langerhans

Eukrohnia hamata (Möbius)

Pl. 2, fig. 8; pl. 4, fig. 35.

Eukrohnia hamata, Ritter-Záhony (1909c), p. 792, (1910), p. 268.
Sagitta hamata Möbius (1875), p. 158.
Spadella hamata, Hertwig (1880), p. 73.
Krohnia hamata, Langerhans (1880), p. 136; Krumbach (1903), p. 639; Strodtmann (1892), p. 20; Fowler (1905), p. 74, (1906), p. 23.
Krohnia foliacea Aida (1897), p. 19.

Characters

Body firm and opaque (pl. 2, fig. 8) as in *S. serratodentata.* Neck well marked. Body thickest throughout middle third, tapering gradually toward head and tail. Muscles heavy and thick. Slight constriction at tail-septum.

Lateral fins long, extending from ventral ganglion to some distance behind tail-septum. They never extend more than half way from tail-septum to seminal vesicles. Widest near plane of tail-septum, sometimes slightly in front and sometimes slightly behind. As described by Fowler (1905), the absence of fin rays seems to be characteristic.

Vestibular ridge apparently absent. According to Fowler (1906, p. 23) there "exists a very slight ridge with sense bulbs in the position of the vestibular ridge in *Sagitta.*" In the San Diego specimens I have been unable to determine this with certainty.

Teeth 10 to 13 in the San Diego specimens. This agrees more nearly with Fowler's (1905) variety of *E. hamata* than with the usual species, which bears from 16 to 22.

Seizing jaws (pl. 4, fig. 35) 8 to 11, similar in form and structure to Krumbach's (1903) description. Jaws with oval cross-section, the pulp very scantily filling center of canal. In some instances the pulp is swollen near the base of the point. Base of point and top of shaft converge upon approaching edge of jaw. Points sickle-shaped, the amount of curvature varying among the individuals and also among the different jaws of the same specimen. Pulp-canal approximately central. Unlike Krumbach (1903), I have been unable to detect any evidence of sagination.

TABLE 14

Measurements of *Eukrohnia hamata*[1]

Number	Length in mm.	Width	Length of tail	Lateral fin: To ventral ganglion	Lateral fin: Length	Lateral fin: Width	Length of ovary	Tail-septum[2]	Number of teeth	Number of seizing jaws
1	13	5.2	28.2	0	52	1.7		80	?–?	8–8
2	14	6.0	32.0	0	77	2.4	25.0	85	10–10	11–10
3	14.5	5.0	29.0	0	58	2.3		86	10–11	9–9
4	14.5	5.0	28.0	0	59	2.7	34.0	84	11–?	10–9
5	15	5.2	29.6	0	44	1.5		77	?–?	9–8
6	15	4.0	29.0	0	63	2.2		82	12–11	9–8
7	15.5	5.6	28.0	0	76	3.9	46.0	88	13–?	10–?
8	17.5	4.3	29.0	0	62	3.3	13.5	80	10–10	10–9

[1] All measurements made in per cent of total length of animal.

[2] Per cent of lateral fin in front of tail-septum.

In most of the specimens the ovaries were well developed and the eggs well toward maturity, but for some unknown reason the upper third of the ovaries had burst and the eggs were scattered throughout the body-cavity. This made it impossible to determine the length of the ovary except in a very few instances.

Eukrohnia hamata is very readily distinguished from both the other species of the genus. To the naked eye it bears considerable resemblance to *Sagitta serratodentata.* In fact the resemblance is so striking that it is difficult to distinguish the two with the naked eye. The microscope, however, readily reveals the difference.

Eukrohnia subtilis (Grassi)

Pl. 2, fig. 9; pl. 3, fig. 25; pl. 4, fig. 36.

Spadella subtilis Grassi (1883), p. 23.

Krohnia subtilis, Strodtmann (1892), p. 22; Fowler (1905), p. 78, (1906), p. 25.

Characters

Body, unlike *E. hamata*, nearly transparent (pl. 2, fig. 9). Extremely

long and slender, the width being about 4 per cent. Body slightly widest between ventral ganglion and origin of lateral fins, tapering very gradually forward and backward from this point. Neck evident. Constriction at tail-septum nearly absent.

Lateral fin extends to seminal vesicles. More than 50 per cent of fin behind tail-septum. The interval between anterior limit of fin and ventral ganglion varies from 17 to 21 per cent.

Vestibular ridge is apparently absent. *Teeth* 10 to 14 in the San Diego specimens. Fowler (1905) records 7 to 13. Unlike *E. pacifica,* the teeth (pl. 3, fig. 25) are not conspicuously bayonet-shaped. *Seizing jaws* (pl. 4, fig. 36), 7 to 9, very flat, broad, thin, and evenly curved. The points are extremely fine and delicate.

TABLE 15

Measurements of *Eukrohnia subtilis*[1]

Number	Length in mm.	Width	Length of tail	Length of ovary	Lateral fin: To ventral ganglion	Lateral fin: Length	Lateral fin: Width	Tail-septum[2]	Number of teeth	Number of seizing jaws
1	13.0	4.0	32	4.9	18	38	4.6	40	12–12	8–9
2	14.5	3.4	34	3.4	17	36	4.4	42	11–12	8–9
3	15.0	4.0	33	6.5	20	35	5.8	36	12–11	7–8
4	14	3.9	31	4.8	20	34	3.9	37	?–?	7–7
5	16	3.7	32	5.9	23	34	3.9	40	12–?	8–8
6	15.5	4.1	31	5.6	18	32	4.6	41	12–12	9–8
7	15.5	3.8	33	6.6	21	33	6.0	44	14–13	8–8
8	14	3.8	33	5.9		34	4.9	35	10–?	8–7
9	12	4.2	30	3.2	20	34	5.1	37	10–?	7–7

[1] All measurements made in per cent of total length of animal.

[2] Per cent of lateral fin in front of tail-septum.

This species is readily distinguished from all other Chaetognatha except *E. pacifica,* to which it bears a remarkably strong resemblance. The few points of difference are as follows. Teeth of *E. subtilis* not so conspicuously bayonet-shaped. Body thinner for its length, and slightly more uniform in width. Seizing jaws thinner and more uniformly curved. Whether these differences are sufficient to distinguish two otherwise almost identical species is doubtful but, owing to the scarcity of material, it is impossible to make a positive statement regarding either their identity or validity.

Genus **Spadella** Langerhans

Spadella draco Krohn

Pl. 2, fig. 10; pl. 3, fig. 23; pl. 4, fig. 37.

Spadella draco Krohn (1853), p. 273; Hertwig (1880), p. 71; Langerhans (1880), p. 136; Grassi (1883), p. 23; Krumbach (1903), p. 628; Fowler (1906), p. 25.
Pterosagitta mediterranea Costa (1869), p. 55.
Spadella vougai Béraneck (1895), p. 155.

Characters

Body firm and opaque (pl. 2, fig. 10), retaining its form well. Neck absent. Collarette very pronounced, measuring in width approximately 0.5 per cent on either side of the body. It extends from head to tail-septum and, in the San Diego specimen, it spreads out over the anterior part of the lateral fin. Muscles heavy and strong. Body, including collarette, nearly of uniform width from head to tail-septum. Ventral ganglion located about midway between tail-septum and head. *Corona ciliata* two-thirds on head, long and elliptical in shape. Lateral fin semicircular in form.

Vestibular ridge (pl. 3, fig. 23) provided with a very few irregular papillae. Notch extends to middle of second tooth. Even the tip of first tooth is covered by the wing so that none are left entirely exposed. External process terminates abruptly just beyond the first tooth. It comprises about 26 per cent of the length of the entire ridge.

The *seizing jaws* (pl. 4, fig. 37) of the single specimen from San Diego bear out Krumbach's (1903) description. The points have an oval base, and are inserted about one-fourth or one-fifth their height into shaft. They are strongly needle-shaped. Pulp-canal central. Upper third of shaft strongly bent. Flat broad-edged crest along edge of shaft.

But one individual of this species was taken. It offers the following measurements:

Length	7 mm.
Width	12.1 per cent
Width without collarette	10.9 per cent
Tail	43.6 per cent
Tail to ventral ganglion	66 per cent
Lateral fin	21.2 × 5.4 per cent
Seizing jaws	8–?
Anterior teeth	4–4
Posterior teeth	9–8

The number of teeth and seizing jaws scarcely agrees with that reported by Krohn (1853) or Hertwig (1880). They record the seizing jaws as 10, anterior teeth 8, posterior teeth 18, while our specimen agrees more nearly with Béraneck's (1895) descrip-

tion of *S. vougae,* the formula of which is 9, 4-5, 6-7. However, the San Diego specimen is very immature, having not the slightest trace of ovary or seminal vesicle.

TABULATION AND DISCUSSION OF THE LENGTH OF OVARIES IN SOME OF THE SAN DIEGO SPECIES OF CHAETOGNATHA

In the following tabulations I have attempted to arrange the specimens of each species in several groups according to maturity of the ovaries. Such a separation is almost entirely a matter of judgment depending upon a combination of characters which baffles exact definition. Length and width of ovary, size and appearance of eggs, tumidity of seminal receptacles, and size of animal are some of the factors that influence judgment concerning maturity, but it is as impossible to define the value of each with respect to the others as it is to define exactly the value of each feature, expression, or mannerism that makes you sure of your acquaintance with a friend. I have, then, separated the stages of maturity, fully realizing the impossibility of stating the exact reason for placing this individual as mature and that one as only approaching maturity. But, crude as it may be, only by such a separation is it possible to consider variations of the mature ovary within a single species.

I have noticed that, in some species, the seminal vesicles and ovaries mature at the same time, while in other species their development is not parallel. In order to prevent the possibility of prejudice in associating the mature ovary with the mature seminal vesicle, the method of making tabulations has been as follows: The first entry concerned the maturity of the ovary; after this was settled, measurements of the ovary were made with an ocular micrometer and recorded. The specimens were then numbered, isolated, and laid aside for at least a week. Having by that time entirely forgotten what the measurements were, I entered on another sheet of paper, against the number of my specimen, my judgment concerning the maturity of the seminal vesicles. The results were then brought together, the measurements reduced to millimeters, and the data arranged as in the following tables.

TABLE 16

Measurements concerning the Ovary in *Sagitta enflata*

Number	Length	Length of ovary in mm.	Length of ovary in per cent[1]	Width of ovary in mm.	Width of ovary in per cent[2]	Distance to posterior fin[3]	Nature of seminal vesicles
			Ovary sexually mature				
1	12.5	1.3	10.1	0.22	17	2.8	mature
2	15.5	1.0	6.7	0.29	29	7.0	mature
3	16	0.7	4.4	0.22	31	7.0	mature
4	16	1.1	6.7	0.34	31	4.3	mature
5	16.5	0.9	5.7	0.40	44	3.8	mature
6	16.5	1.2	7.2	0.35	29	2.7	mature
7	17	1.2	6.7	0.34	31	3.7	mature
8	17.5	1.1	6.1	0.33	30	3.9	mature
9	17.5	1.3	7.7	0.33	25	3.9	mature
10	18	1.0	5.4	0.29	29	6.3	mature
11	18	1.1	6.3	0.33	30	3.1	mature
12	18.5	1.0	5.3	0.33	33	3.8	mature
13	18.5	1.4	7.4	0.33	24	3.4	mature
14	19.5	1.2	6.2	0.28	23	4.7	mature
			Ovary approaching maturity				
15	15	0.57	3.8	0.14	25	5.7	nearly mature
16	15	0.53	3.5	0.15	28	5.0	nearly mature
17	15.5	0.57	3.7	0.15	26	7.5	nearly mature
18	16	0.47	2.9	0.16	34	9.3	nearly mature
19	16	0.53	3.3	0.26	47	5.5	nearly mature
20	16	0.63	3.9	0.20	32	4.4	nearly mature
21	16.5	0.69	4.2	0.23	33	5.6	nearly mature
22	17.5	0.58	3.3	0.12	21	9.8	nearly mature
			Ovary remote from maturity				
23	8	0.00	0.0	0.00	0		invisible
24	9	0.28	3.1	0.05	18	?	invisible
25	10.5	0.31	3.0	0.05	16	9.6	barely visible
26	11	0.22	2.0	0.06	27	?	invisible
27	12	0.34	2.8	0.08	24	6.5	barely visible
28	12.5	0.38	3.0	0.06	16	9.9	barely visible
29	12.5	0.35	2.8	0.09	26	9.5	barely visible
30	13	0.35	2.7	0.09	26	9.0	invisible
31	13.5	0.34	2.5	0.11	32	7.2	barely visible
32	14	0.39	2.8	0.11	28	6.8	barely visible
33	15.5	0.70	4.5	0.17	24	8.2	barely visible

[1] Measured in per cent of total length of animal.

[2] Measured in per cent of total length of ovary.

[3] Distance from anterior end of ovary to anterior end of posterior fin measured in per cent of total length of animal.

From these data we may arrive at the following tentative conclusions:

1. The ovary commences development first but, as a rule, it reaches maturity at the same time as the seminal vesicle.
2. The mature ovary (pl. 5, fig. 39) varies in length from 5 to 10 per cent of the total length of the animal, or from 0.7 to 1.4 mm.
3. In width the mature ovary varies from slightly under one-sixth to slightly over one-third its length.
4. In extent the mature ovary never reaches the anterior limit of the posterior fin.

So far as I am acquainted with the literature, Ritter-Záhony (1908) has been the only investigator who has attempted to make a systematic tabulation of the length of ovary. From his records for *S. enflata* I have extracted the following data:

Length of specimen in mm.	Length of ovary in mm.
9	0.25
10	0.25
11	0.25–1.0
12	0.60
13	1.00–1.8
14	0.80
15	0.50–1.2
16	0.50–1.1
17	0.70–2.2
18	1.00–1.8
19	1.00–1.5
20	0.90–1.6
21–23.3	1.50–2.0

A comparison of these data with the above table shows an agreement much closer than anyone would have expected. Taken as a whole, the ovary in his specimens attains a greater length (2.2 mm.) that those from San Diego (1.4 mm.).

TABLE 17

Measurement concerning the Ovary in *Sagitta bipunctata*

Number	Length in mm.	Length of ovary in mm.	Length of ovary in per cent[1]	Width of ovary in mm.	Width of ovary in per cent[2]	Distance to posterior fin[3]	Nature of seminal vesicles
			Ovary sexually mature				
1	10	1.7	17.3	0.34	20.0	+4.0	mature
2	10	1.4	13.6	0.23	16.7	—1.7	mature
3	10.5	1.3	12.5	0.23	17.4	0.0	mature
4	11.5	1.7	14.8	0.23	13.3	0.0	nearly mature
5	12	1.8	15.0	0.30	16.6	0.0	mature
6	12	1.3	11.1	0.23	17.9	+2.8	mature
7	12.5	1.9	15.2	0.29	15.2	+1.4	mature
8	12.5	2.1	16.6	0.23	16.8	0.0	nearly mature
9	13	1.6	12.1	0.30	18.5	—0.9	mature
10	13	1.8	13.9	0.29	16.1	—1.3	mature
11	13	1.5	11.8	0.23	15.4	—3.2	mature
12	13	1.5	11.6	0.26	17.2	—1.3	mature
13	13	1.9	14.4	0.30	15.6	0.0	mature
14	14	1.6	11.2	0.24	14.8	0.0	mature
15	14	2.0	14.5	0.29	14.3	0.0	mature
16	14	2.7	19.4	0.29	10.6	+2.5	mature
			Ovary approaching maturity				
17	11.5	1.1	9.5	0.17	15.8	—5.0	immature
18	11.5	1.0	9.1	0.14	13.9	—5.1	immature
19	11.5	0.98	8.6	0.14	14.7	—5.6	immature
20	12	1.0	8.7	0.11	11.1	—7.3	immature
21	12	0.94	7.8	0.12	12.5	—6.8	immature
22	12.5	1.3	10.5	0.27	20.8	—3.7	nearly mature
23	12.5	1.4	11.0	0.23	16.6	—5.5	nearly mature
24	13	1.3	10.0	0.21	15.9	—4.5	nearly mature
25	13	1.6	12.3	0.17	10.7	—4.0	nearly mature
			Ovary remote from maturity				
26	8.5	0.51	6.0	0.11	22.2	—10.6	barely visible
27	9	0.44	4.9	0.06	12.5	—8.0	barely visible
28	9.5	0.49	5.1	0.09	17.6	—6.6	barely visible
29	10	0.63	6.3	0.12	18.2	—9.7	barely visible
30	10	0.52	5.2	0.12	22.2	—5.7	barely visible
31	10.5	0.44	4.2	0.09	20.0	—11.7	barely visible
32	11	0.57	5.2	0.09	15.0	—10.5	barely visible

[1] Measured in per cent of total length of animal.

[2] Measured in per cent of total length of ovary.

[3] Distance from anterior end of ovary to anterior end of posterior fin measured in per cent of total length of animal. The + sign signifies that the ovary is anterior, and the — sign that it is posterior to this point.

The table presents the following generalizations:

1. As in *S. enflata,* the ovary and seminal vesicles reach maturity at aproximately the same time.
2. The mature ovary (pl. 5, fig. 40) varies in length from 1.3 to 2.7 mm. or from 11 to 20 per cent of total length of specimen.
3. In width the mature ovary varies from 0.22 to 0.35 mm. or from 10.5 to 20 per cent of its own length.
4. The mature ovary reaches the anterior limit of the posterior fin, the variation on either side of this point being about 4 per cent.

Ritter-Záhony (1910, p. 256) gives the length of mature ovary in individuals ranging from 9 to 12 mm. as from 1.2 to 1.8 mm., or from 13 to 15 per cent of the total length of the individual.

TABLE 18

Measurements concerning the Ovary in *Sagitta lyra.*

Ovary remote from maturity

Number	Length in mm.	Length of ovary		Width of ovary		Ovary to ventral ganglion[1]	Nature of seminal vesicles
		in mm.	in per cent[1]	in mm.	in per cent[2]		
1	20	0.00	0.0	0.00	0.0		not visible
2	20	0.38	1.9	0.06	16.7	—60.5	barely visible
3	24	0.70	2.9	0.06	9.1	—54.6	barely visible
4	24	1.92	8.0	0.06	3.3	—40.0	barely visible
5	25	0.00	0.0	0.00	0.0		not visible
6	28	0.00	0.0	0.00	0.0		not visible
7	28	2.20	8.0	0.06	2.9	—58.0	barely visible
8	29	2.20	7.7	0.06	4.3	—38.6	barely visible
9	31	3.07	9.9	0.19	6.25	—57.2	barely visible
10	32	1.28	7.5	0.09	7.5	—55.9	barely visible
11	32	2.90	9.0	0.13	4.5	—62.0	barely visible
12	33	2.00	6.2	0.13	6.3	—57.5	not visible
13	33	5.70	17.3	0.19	3.3	—44.3	barely visible
14	34	3.80	11.3	0.19	5.0	—32.9	barely visible
15	35	2.70	7.6	0.13	4.8	—38.8	not visible
16	36	4.70	13.0	0.19	4.1	—35.4	barely visible
17	37	6.10	16.4	0.19	3.2	—35.4	not visible
18	40	5.80	14.5	0.06	1.1	—29.4	not visible

[1] Measured in per cent of total length of animal.

[2] Measured in per cent of total length of ovary.

Table 18—*Continued*

Number	Length in mm.	Length of ovary in mm.	Length of ovary in per cent	Width of ovary in mm.	Width of ovary in per cent	Ovary to ventral ganglion[1]	Nature of seminal vesicles
Ovary immature							
19	45	7.80	17.3	0.19	2.5	—42.5	barely visible
20	45	7.75	17.2	0.26	3.3	—42.5	well developed
21	49	5.70	11.7	0.22	3.9	—50.4	barely visible
Ovary approaching maturity							
22	36	15.30	41.8	0.25	1.6	—4.1	well developed
23	44	9.90	22.5	0.26	2.6	—25.4	well developed
24	52	12.00	23.3	0.32	2.6	—27.0	well developed
Three specimens sent by Broch from the North Sea.							
25	55	4.00	7.3	0.25	6.3	—38.2	not visible
26	71	6.00	8.5	0.50	8.3	—36.6	barely visible
27	75	11.00	14.7	1.50	7.3	—29.4	nearly mature

In the entire twenty-seven specimens there is none that appears to me to be fully mature. No. 22 (pl. 6, fig. 43) evidently has most nearly attained this condition, and I suspect that an examination of a larger series of individuals than the San Diego catches afford would show that the ventral ganglion is the object about which the maximum length of ovary fluctuates. Apparently the seminal vesicles may mature before the ovaries. Concerning this Ritter-Záhony (1908, p. 12) says: "Zur Zeit der männlichen Reife sind die Ovarien noch verhältnissmässig kurz; ihre völlige Reife fällt." This seems to indicate that the ovaries attain their complete maturity very rapidly during the last period of life. On his specimens of *S. lyra* Ritter-Záhony (1908) makes the following measurements:

Length of specimen in mm.	Length of ovary in mm.
16	0.8
18	1.0–1.5
19	1.6
21	2.8
22	0.75
25	0.35–1.8
26	0.25–0.75
27	0.5
28	1.0
29	0.5–2.2
30	2.2

For the lengths of individual paralleled in the San Diego material, the length of ovary corresponds as closely as one would expect, but as most of our specimens are very much larger an exact comparison is impossible. (Compare also the measurements recorded by Ritter-Záhony, 1910, pp. 265-6 for *S. maxima.*)

TABLE 19

Measurements concerning the Ovary in *Sagitta planktonis.*

Number	Length in mm.	Length of ovary in mm.	Length of ovary in per cent[1]	Width of ovary in mm.	Width of ovary in per cent[2]	Distance to posterior fin[1]	Distance to ventral ganglion[1]	Nature of seminal vesicles
Ovary approaching maturity								
1	25	9.9	39.6	0.250	2.5	+32.0	0.0	well developed
2	24	11.4	47.5	0.136	1.2	+36.5	—6.8	nearly mature
3	24	11.0	46.0	0.217	2.0	+25.0	0.0	well developed
4	21	7.7	36.5	0.164	2.1	+23.5	—7.8	well developed
5	18.5	4.7	25.4	0.193	4.1	+13.4	—1.5	well developed
6	14.5	4.4	30.0	0.190	4.4	+20.6	—2.1	nearly mature
Ovary well developed								
7	24.5	5.0	20.5	0.192	3.8	+ 9.0	—20.3	nearly mature
8	24	5.3	22.0	0.165	3.1	+10.4	—17.3	well developed
Ovary remote from maturity								
9	19	1.6	8.6	0.027	1.6	—2.9	—33.0	invisible
10	17.6	1.4	8.1	0.027	1.9	—6.3	—47.0	invisible
11	17	1.7	10.0	0.085	5.0	+5.6	—34.6	barely visible
12	16.5	1.7	10.0	0.116	6.7	+5.5	—28.9	barely visible
13	13	0.7	5.1	0.027	4.2	—4.2	—38.0	invisible
14	11.5	0.0		0.000				invisible

[1] Measured in per cent of total length of animal.
[2] Measured in per cent of total length of ovary.

As in the case of *S. lyra,* none of the specimens examined appeared to be fully mature. Nos. 2 and 3 (pl. 5, fig. 42) approximate most nearly to complete maturity, which fact would indicate that the mature ovary extends nearly to the ventral ganglion.

TABLE 20

Measurements concerning the Ovary in *Sagitta serratodentata.*

Number	Length in mm.	Length of ovary in mm.	Length of ovary in per cent[1]	Width of ovary in mm.	Width of ovary in per cent[2]	Distance to posterior fin[1]	Distance to ventral ganglion[1]	Nature of seminal vesicles
Ovary approaching maturity								
1	14	6.2	44.0	0.31	5.0	+26.4	0.0	mature
2	15	4.5	30.4	0.33	7.4	+14.8	—1.8	nearly mature
3	16	4.5	28.2	0.34	7.5	+15.5	—7.0	nearly mature
4	17	5.3	31.3	0.32	6.0	+14.5	—19.8	invisible
5	17	4.9	29.2	0.49	10.0	+18.7	—20.8	barely visible
Ovary well developed								
6	13	3.0	23.0	0.28	9.3	+8.1		well developed
7	14	2.2	21.2	0.33	14.8	+8.1	—27.8	barely visible
8	16	3.5	22.2	0.28	8.0	+10.0	—25.6	barely visible
9	18	3.5	19.3	0.36	10.2	+7.9	—28.6	approaching maturity
Ovary remote from maturity								
10	12.5	2.1	16.9	0.28	13.2			well developed
11	13	2.7	20.6	0.16	6.0			well developed
12	13	0.8	5.9	0.11	14.3	—5.5		barely visible
13	14	0.9	6.7	0.12	11.7	—3.5		barely visible
14	14	2.4	16.9	0.22	9.8	+5.9		well developed
15	14.5	1.9	13.4	0.31	16.4	+7.3	—30.8	barely visible
16	15	1.8	11.9	0.25	14.0	0.0		well developed
17	15.5	1.8	11.4	0.11	6.0	0.0	—32.0	barely visible
18	15.5	1.2	8.0	0.10	8.6	—2.7	—29.6	well developed
19	16	2.5	15.6	0.28	11.1	+3.5		well developed
20	17	2.3	13.5	0.22	9.8	+4.6		well developed
21	18.5	1.3	6.9	0.14	11.1	—4.8	—39.7	invisible

[1] Measured in per cent of total length of animal.
[2] Measured in per cent of total length of ovary.

But one specimen (no. 1) appeared to be fully mature (pl. 5, fig. 41), although the first five seemed to be very nearly so. With some allowance I think we may draw the following conclusions:

1. The ovary approaches maturity when its length lies between 28 and 44 per cent of the total length of the specimen.
2. The mature ovary extends very nearly to the ventral ganglion.
3. The seminal vesicles may apparently be in any stage of development when the ovary is mature.

TABLE 21

Measurements concerning the Ovary in *Sagitta neglecta.*

Number	Length in mm.	Length of ovary		Width of ovary		Distance to posterior fin[1]	Nature of seminal vesicles
		in mm.	in per cent[1]	in mm.	in per cent[2]		
1	10	0.57	5.7	0.076	13.3	—9.1	barely visible
2	10	0.76	7.6	0.076	10.0	—3.8	barely visible
3	11	1.2	11.3	0.054	4.5	0.0	nearly mature
4	12	0.9	7.5	0.081	6.3	—2.2	barely visible
5	12	0.9	7.5	0.081	6.3	—2.5	well developed
6	12	1.2	9.7	0.058	4.8	—1.9	well developed
7	12.5	0.95	7.6	0.057	6.0	—2.1	well developed
8	13	1.9	15.1	0.146	7.7	0.0	nearly mature
9	14	1.1	8.1	0.074	6.7	—4.3	barely visible
10	14.5	0.8	5.7	0.054	6.8	—2.1	barely visible
11	14.5	1.7	11.5	0.097	5.7	+2.6	barely visible

[1] Measured in per cent of total length of animal.
[2] Measured in per cent of total length of ovary.

In the eleven specimens there is not a single instance of anything approaching maturity. Nos. 3, 8, and 11, according to my notes, are marked "well-developed but scarcely approaching maturity." All the others are clearly remote from maturity. The probabilites are that no. 8 represents nearly the maximum length of the ovary, but of this I can not be certain until I have more material with which to work.

The specimens of other species from this region in our collections are too few in number or too immature to allow any significant measurements of the ovary. We may however, in a general manner, divide the San Diego *Sagitta* into two groups.

1. Ovary long and slender, extending nearly to the ventral ganglion. This group includes *S. planktonis, S. hexaptera, S. lyra,* and *S. serratodentata.*

2. Ovary short and thick, never extending much beyond the anterior limit of the posterior fin. This group includes *S. enflata, S. bipunctata,* and probably *S. neglecta.*

These groups are very apparently different, even at first

glance, least so among smaller individuals, but becoming more and more apparent as the length of specimen increases. I believe an extensive tabulation in this regard would present definite differences of much value in classification.

REDESCRIPTIONS OF SOME DOUBTFUL SPECIES OF CHAETOGNATHA

Sagitta hispida Conant

Sagitta hispida Conant (1895), p. 78, fig. 7; Aida (1897), p. 18.
Sagitta robusta Doncaster (1902b), p. 212; Fowler (1906), p. 19.

After some difficulty I have been fortunate enough to obtain one specimen of *S. hispida* which was identified by Conant himself. The specimen was obtained from Beaufort, North Carolina, and deposited in the United States National Museum. Through the courtesy of that institution I have been enabled to restudy the species.

The specimen is not in the best conditon for extensive study, so that there are many points which can not be determined. Like many Chaetognatha when preserved in alcohol, this specimen has not only shrunken, thereby making the width measurements appear too small, but it has also turned almost black, making it impossible to count the teeth or seizing jaws, or to locate the ventral ganglion. However, in connection with the literature, I believe the specimen presents enough facts to permit us with safety to identify it with *S. robusta* Doncaster.

Below is given a table of comparison for the two species, the information for which has been obtained from Doncaster (1902b), and Fowler (1906) for *S. robusta,* and from Conant (1895), and from the above-mentioned specimen for *S. hispida.*

TABLE 22

Comparison of *S. hispida* and *S. robusta*

Characters	*S. hispida*	*S. robusta*
Length in mm.	5.5–11	10–14
Width in per cent of length	4.2–4.3	5.7
Lateral fields	small	small
Muscles	strong	strong
Consistency	firm	firm

TABLE 22—*Continued*

Appearance	opaque	opaque
Collarette	present	present
Tail in per cent of length	28–33	25–33
Anterior fin, length and width	13–19 × 3.8 per cent	20 × 2.9 per cent
Anterior fin, to posterior fin	6.3–8.7 per cent	6.8 per cent
Posterior fin, length and width	23–28 × 4.9 per cent	26 × 3.7 per cent
Posterior fin, extends caudally	to seminal vesicles	to seminal vesicles
Posterior fin, greatest width	behind tail-septum	behind tail-septum
Posterior fin, per cent in front of tail-septum	36–40	35
Seizing jaws	8–9	5–7
Anterior teeth	4–5	5–10
Posterior teeth	8–15	11–14

In addition to the above characters, others not easily presented in tabular form are essentially the same in the two species. The form of the body, position of greatest width, and the gradual diminution on approaching either head or tail are very similar in the two forms. Again, the form of the fins is nearly the same. Finally, the extent of collarette and the position and form of *corona ciliata* are greatly alike.

A careful examination of the above table reveals but five points of difference. They consist of width, width of anterior fin, width of posterior fin, number of anterior teeth, and number of seizing jaws. Let us then look at these differences a little more closely.

1. Width of Body. Owing to inshrinking of the lateral fields, my measurement of 4.3 per cent is probably too small to represent the width in fresh or living material. Granting, however, that 4.3 per cent is the true width, an examination of width measurements of the San Diego species reveals greater variation than from 4.3 to 5.7 per cent. *S. enflata* varies from 6 to 12 per cent, *S. hexaptera* from 7 to 11 per cent, *S. lyra* from 6.3 to 10.5 per cent, and *S. serratodentata* from 3.4 to 6.5 per cent. Other species show as great variation. It seems, therefore, that this difference between *S. hispida* and *S. robusta* is of no specific importance.

2. Width of Anterior Fin. It was impossible to measure the width of anterior fin in the single specimen I had occasion to examine. Assuming, however, that Conant's (1895) measurement of 3.8 per cent is correct, we find that a variation from 2.9 to 3.8 per cent is no greater than the individual variations in this regard of some of the San Diego species. *S. enflata* varies from 1.0 to 2.8 per cent, *S. bipunctata* from 1.4 to 2.5 per cent, and many of the other species show as great variations. It is evident that this difference does not signify the existence of two species.

3. Width of Posterior Fin. The width of posterior fin of *S. robusta* is 3.7 per cent and that of *S. hispida* is 4.9 per cent. Nearly every San Diego species, however, presents a much greater variation. In *S. bipunctata* the fin varies from 3.1 to 4.5 per cent, in *S. planktonis* from 3.1 to 5.4 per cent, and in *S. enflata* from 2.6 to 5.7 per cent. It is probable, therefore, that this difference is only a measure of individual variation and not of specific difference.

4. Number of Anterior Teeth. Conant (1895) records the number of anterior teeth as 4 to 5, while in *S. robusta* there are 5 to 10. This looks like a more significant difference. Let us see how it bears comparison with other species. In individuals of *S. serratodentata* varying in length from 6 to 14 mm., Fowler (1905, p. 59) records the variation in anterior teeth as 3 to 6.

TABLE 23

Variation in Anterior Teeth in *S. serratodentata*

Length of specimen in mm.	Biscayan report Fowler (1905)	"Siboga" report Fowler (1906)
14	5–6	9–10
12	4–7	9
11	6	8–9
10	4–6	8–9
6–9	3–4	5–9

In the "Siboga" Report (1906, p. 20), however, he finds a variation from 5 to 10 corresponding to individuals of similar lengths. Even a careful comparison of the number of anterior teeth recorded in the Biscayan and "Siboga" Reports, as given

in table 23 does not show a single case of overlapping in the entire series.

Again, Fowler (1906, p. 9) finds the number of anterior teeth in *S. enflata* greater than we have found in San Diego specimens of the same lengths. Table 24 shows that, as in the

TABLE 24

Variation in Anterior Teeth in *S. enflata*

Length of specimen in mm.	"Siboga" area	San Diego region
20	8–9	5–6
17	8–9	6–7
16	8	6–7
15	8–9	6–7
12	9	6

case of *S. serratodentata,* there is not a single case of overlapping.

Finally, in *S. sibogae* we discover a similar difference between those species obtained by Fowler (1906) and those taken by Ritter-Záhony (1909b). This difference is illustrated in table 25.

TABLE 25

Variation in Anterior Teeth of *S. sibogae*

Length of specimen in mm.	Fowler (1905)	Ritter-Záhony (1909)
11	7	10–12
10	7	9–11
9	8	7–13

Similar instances might be given, but enough has been said to prove that a wide variation in number of anterior teeth occurs in individuals of the same species. Furthermore, in the cases cited, the difference is greater than that found between *S. hispida* and *S. robusta.*

Considerable space has been utilized in this discussion of teeth relations because Fowler (1906) saw in this difference a reason for not identifying the two species in question. He remarked upon the similarity betwen the two forms and after identifying Aida's *S. hispida* with *S. robusta* concluded (p. 20): "At any rate it is apparent from the marked difference in

number of anterior teeth that they [*S. hispida* Aida] were not *hispida* Conant." It seems, however, that variation in number of both anterior and posterior teeth in many species is not referable to specific differences, but probably to some distribution factor.

5. Number of Seizing Jaws. In number of seizing jaws we found that *S. robusta* varies from 5 to 7, while *S. hispida* has only 8 or 9. Shall we claim that this is of specific value? In looking over this paper we find the following variations in number of seizing jaws:

TABLE 26

Number of Seizing Jaws in the San Diego species.

Species	Number of jaws	Comparison with other reports	
S. enflata	8–9	6–10	Fowler (1906)
S. hexaptera	5–9	3–9	Fowler (1906)
S. lyra	4–9	7–9	Ritter-Záhony (1909)
S. serratodentata	5–7	6–8	Fowler (1905)
S. planktonis	8–9	8–10	Fowler (1905)
S. neglecta	7–9	5–8	Fowler (1906)
S. bipunctata	7–8	8–10	Fowler (1905)

A glance at this table shows that, in *S. enflata, S. hexaptera, S. lyra,* and *S. neglecta,* a variation of four or more seizing jaws occurs. We can be sure, therefore, that such a variation may be within the range of a single species. Finally, when we consider Aida's *S. hispida,* it becomes all the more probable that *S. hispida* Conant and *S. robusta* Doncaster are the same species, for the reason that Aida's specimens have 7 or 8 seizing jaws.

It is to be regretted that there was not more than one specimen of *S. hispida* at my disposal and that for this reason it has been impossible to dissect it and so draw and describe many of the features rendered obscure by its long preservation and discoloration. Nevertheless, I am convinced that the two species are identical. *S. hispida* Conant should, therefore, have prior claim and *S. robusta* Doncaster must take its place in synonymy.

Sagitta elegans Verrill

Pl. 2, figs. 12, 13; pl. 3, fig. 24; pl. 4, fig. 38.

Sagitta elegans Verrill (1873), p. 332; Conant (1896), p. 84.
Sagitta arctica Aurivillius (1896), p. 188.
Sagitta gracilis, Verrill (1883) [see Conant (1896), p. 84].
Sagitta bipunctata, Krumbach (1903), p. 628.
Sagitta bipunctata forma arctica, Ritter-Záhony (1910), p. 256.

Through the courtesy of the United States National Museum I have been enabled to study a few specimens of Verrill's *S. elegans.* The specimens were originally obtained from Vineyard Sound, Massachusetts. From Dr. Hjalmar Broch, of Christiania, Norway, I have also some specimens of *S. arctica,* obtained November 16, 1905, from the Skagerak. Fowler (1906) pointed out that these two forms were probably to be identified as a single species, and later Ritter-Záhony (1910) synonymized them with *S. bipunctata.* It is, therefore, advisable to redescribe them and inasmuch as they are so nearly alike (pl. 2, figs. 12, 13), I shall describe *S. elegans* and then briefly consider the main points in which it differs from *S. arctica.*

Characters

Body opaque (pl. 2, fig. 12), but rather flabby. Neck well marked, but scarcely so pronounced as in *S. enflata* or *S. hexaptera.* Body widest throughout posterior third, tapering gradually toward head and more rapidly toward tail. Lateral fields conspicuous but not large. Muscles strong and thick. Diminution at tail-septum rather abrupt. Collarette absent.

Anterior fin situated well forward, shorter and narrower than posterior fin. It does not extend to the ventral ganglion, the interval measuring about 6 per cent. Approximately triangular in form, the point of greatest width being located well toward its posterior end. Interval from anterior to posterior fin about 12 per cent.

Posterior fin extends nearly, if not quite, to seminal vesicles. Always more than 50 per cent of fin in front of tail-septum, and usually more than 60 per cent. Position of greatest width slightly behind tail-septum.

Vestibular ridge (pl. 3, fig. 24) provided with low, rounded papillae which are rather irregular in height and position. They are not so numerous as the posterior teeth. Four or five teeth usually project beyond wing of ridge. The external process could not be discerned.

Anterior teeth 6 to 11. *Posterior teeth* 13 to 17.

Seizing jaws (pl. 4 fig. 38) 9 to 12 in number, and of much the same form as described by Krumbach (1903) for *S. bipunctata.* Points needle-shaped but with the apex lying slightly nearer edge of jaw. Base of point

and top of shaft parallel. Point inserted into shaft about one-fifth its own height. Pulp-canal slightly swollen just below point, and located somewhat nearer back of jaw. Pulp evenly distributed.

But two specimens were well enough preserved to permit accurate measurements. They are given below, following which the measurements of *S. arctica* are given.

TABLE 27

Measurements of *Sagitta elegans*[1]

Number	Length in mm.	Width	Length of tail	Tail to ventral ganglion	Anterior fin: To ventral ganglion	Anterior fin: Length	Anterior fin: Width	Anterior fin: To posterior fin	Posterior fin: Length	Posterior fin: Width	Tail-septum[2]
1	23	6.9	22	68	6.1	13.9	?	13.0	21.8	?	64
2	21	6.5	23	69	9.0	12.1	?	12.3	20.0	?	63
Measurements of *Sagitta arctica*[1]											
1	24	6.0	21	71.5	11.0	14.5	1.2	11.0	21.6	2.8	68
2	24	6.6	21	74.5	10.3	17.8	1.4	9.9	21.4	2.9	70
3	26	6.4	21	73.0	14.0	13.2	1.0	12.5	21.2	2.9	66
4	27	6.8	22	69.0	12.0	13.9	1.0	11.0	16.0	2.8	61
5	27	6.1	21	73.0	11.0	17.4	1.1	10.4	20.2	2.8	65
6	27	6.0	21	71.5	13.2	14.9	1.4	8.6	21.0	2.6	66
7	27	6.3	22	72.5	9.3	17.4	1.3	10.4	20.8	2.8	63
8	27	6.3	20	73.5	9.7	16.7	1.1	13.6	19.5	2.6	68
9	28	7.0	21	71.0	8.8	16.3	1.6	11.9	18.5	3.3	70
10	28	6.3	20	69.0	9.8	15.0	1.1	11.8	18.9	2.6	66
11	29	6.3	21	71.0	11.5	16.2	1.2	10.5	19.0	2.5	65
12	29	6.1	19	67.5	12.0	13.6	1.2	9.6	10.0	2.0	66

[1] All measurements made in per cent of total length of animal.

[2] Per cent of posterior fin in front of tail-septum.

Anterior teeth in *S. arctica* 7-8, posterior teeth 13-14, seizing jaws 10-11.

This table presents a great similarity between the two species. The only noticeable difference is that, as a rule, the interval from anterior fin to ventral ganglion is larger in *S. arctica*. However, in nos. 7, 8, and 9 we see transition cases.

The other differences between *S. elegans* and *S. arctica* are as follows:

1. The body of the former is flabby, while that of *S. arctica* is firm.

2. *S. elegans* matures sexually at 23 mm., while in none of the specimens of *S. arctica* examined were the ovaries even well developed, nor the seminal vesicles evident.
3. The ovary is slightly broader and longer in *S. elegans.*

Outside of these points the two species are nearly identical. Inasmuch as the specimens of *S. elegans* were preserved in alcohol, and those of *S. arctica* in formalin, the fact that the former is more flabby loses most of its significance. The other two points are interdependent, for in individuals that are sexually mature we should expect the ovary to be slightly longer and broader. Finally, as to the size at which specimens mature, we have noticed considerable variation in such species as *S. enflata* and *S. hexaptera.* From this evidence we are compelled to place *S. elegans* and *S. arctica* in the same species, and as Fowler (1906) has pointed out, the former takes priority, and *S. arctica* becomes a synonym.

Having concluded that the two species are synonymous it remains to see whether *S. elegans* stands as a valid species or whether it must, in turn, be placed in the synonymy of another species.

Being without a collarette *S. elegans* naturally falls into the group with *S. enflata, S. hexaptera, S. lyra, S. bedoti, S. serratodentata,* and *S. macrocephala.* Being opaque and provided with strong muscles it is readily separable from the first three. From *S. bedoti* it is easily distinguished by the fact that *S. elegans* has more than 50 per cent of posterior fin in front of tail-septum, by the presence of a considerable interval between anterior fin and ventral ganglion, and by the fact that the posterior fin is longer than the anterior fin. From *S. serratodentata* it differs in the absence of serrations on the seizing jaws, in an interval between anterior fin and ventral ganglion, and in the presence of more than 50 per cent of posterior fin in front of tail-septum. Finally, it differs from *S. macrocephala* in having a much shorter tail, in the number of posterior teeth, and in the general form of the body.

Fowler (1906) suggested the possible synonymy of *S. elegans* and *S. zetesios* (which has been identified by Ritter-Záhony

(1909c) with *S. planktonis* Steinhaus). While the form of the body and degree of opacity is very similar, they differ radically from one another. In *S. zetesios* the heavy collarette serves to distinguish at once between the two. The anterior fins are also longer than the posterior fins, and originate at the ventral ganglion in the latter species.

According to Ritter-Záhony (1910), *S. elegans* is identified as a variety of *S. bipunctata.* He recognizes two varieties of the latter species, one of which he calls forma *typica,* and the other forma *arctica.* While there is great similarity between them there seems to be as much difference as that between some other species. In the first place I am unable to discover the least trace of collarette in *S. elegans,* whereas in *S. bipunctata* that structure, while not pronounced, is conspicuous. Then, the muscles in *S. bipunctata* are weak, the body is nearly transparent, the seizing jaws are not so numerous, and the general appearance is decidedly contrasted to that of *S. elegans.* The proportional measurements are, however, annoyingly alike, and altogether *S. elegans* resembles *S. bipunctata* more than any other species. However, from the fact that the few differences mentioned are so distinctive and the general appearance so radically different, it seems best to let *S. elegans* remain a valid species.

Sagitta tenuis Conant

Pl. 2, fig. 11.

Sagitta tenuis Conant (1896), p. 85.

The receipt of three specimens of *S. tenuis* from the United States National Museum made it possible to redescribe this species. The specimens are labeled as cotypes obtained from Jamaica, West Indies. They were all damaged, making it impossible to obtain as complete a description as desired.

Characters

Collarette present, but exceedingly small, as in *S. bipunctata.* Body semi-opaque and firm (pl. 2, fig. 11). Muscles strong. Body widest at about middle of its length. From this point it tapers gradually toward head, and more rapidly toward tail. Neck nearly absent. Constriction at tail-septum pronounced, as in *S. enflata.*

Anterior fin beginning on a level with ventral ganglion. Shorter than posterior fin. In length it varies from 12 to 13 per cent.

Posterior fin longer than anterior fin with less than 50 per cent of its length in front of tail-septum. It extends nearly, if not quite, to

seminal vesicles. Interval from anterior fin to posterior fin is rather large, varying from 16 to 17 per cent.

Seizing jaws 8, *Anterior teeth* 5, *Posterior teeth* 9. The width of the fins could not be determined, owing to the fact that a considerable portion had been torn away. Furthermore, the vestibular ridge could not be seen without dissection, which was impossible under the circumstances.

The following measurements were made:

Length	5–5.5 mm.
Width	6 per cent
Tail	29 per cent
Anterior fin in length	12.7 per cent
Anterior to posterior fin	16.3 per cent
Posterior fin in length	25.6 per cent
Per cent of posterior fin in front of septum	43
Tail to ventral ganglion	68 per cent

Conant (1896, p. 85) found that *S. tenuis* resembled *S. hispida* very closely. He says: "Shape of fins, of seizing hooks, *corona ciliata,* accessory longitudinal septa in caudal segment, number of tactile prominences, and musculature of body,—as in *S. hispida.*" That they are not the same species Conant (1896) recognized because *S. tenuis* attains sexual maturity at such a small size. In addition, it differs from *S. hispida* in that the anterior fins originate at the ventral ganglion, and that there is less than 50 per cent of posterior fin in front of tail-septum.

Ritter-Záhony (1910) places *S. tenuis* in the synonymy of *S. bipunctata.* The fact that there is more than 50 per cent of posterior fin in front of tail-septum, and that there is a considerable interval between anterior fin and ventral ganglion in *S. bipunctata* makes me skeptical of such synonymy. Add to this the fact of sexual maturity in *S. tenuis* at a length of 5 mm., and it becomes readily distinguishable from all other species, with the possible exception of *S. minima.*

BRIEF DESCRIPTIONS OF SPECIES NOT YET TAKEN FROM THE SAN DIEGO REGION

For the benefit of those future investigators who may have occasion to identify the Chaetognatha of this region, I have included brief descriptions of the species not yet taken from this vicinity. Such species are *Sagitta decipiens, S. sibogae, S. ferox, S. regularis, S. pulchra, S. bedoti, S. macrocephala, S.*

gazelle, Eukrohnia pacifica and *Spadella cephaloptera.* Owing to the inadequacy of descriptions, and the impossibility of obtaining authenticated specimens, *S. minima* is not considered.

Sagitta decipiens Fowler

Fowler (1905), p. 70, pl. 5, figs. 32-35.

Collarette present, but very short. Body transparent, firm, slender, and widest behind middle of length, tapering gradually toward each end. Neck not well marked. Anterior fin shorter and narrower than posterior fin, not extending to ventral ganglion. Posterior fin widest at or just behind tail-septum. More than 50 per cent of posterior fin in front of tail-septum. No diminution at tail-septum. Ovary short and thick. Ova large. Vestibular ridge prominent, with thick cuticle and long external process sometimes forked. Anterior teeth 5-10. Posterior teeth 12-18. Seizing jaws 5-6. Tail 25-40 per cent of total length.

Sagitta sibogae Fowler

Fowler (1906), p. 12, pl. 2, figs. 66-72.

Collarette present, but short. Body firm, opaque, and widest at middle point, tapering gradually forward and more rapidly backward. Head large. Neck large. Lateral fields medium. Muscles strong. Anterior fins longer and narrower than posterior fins, extending to ventral ganglion. Posterior fins widest at plane of tail-septum, with slightly more than 50 per cent in front of tail-septum. It never extends to seminal vesicles. Vestibular ridge with numerous large and fairly regular papillae. Anterior teeth 7-11, short with broad bases. Posterior teeth 13-23. Seizing jaws 5-7. Tail 21-33 per cent of total length.

Sagitta ferox Doncaster

Doncaster (1903), p. 212.
Fowler (1906), p. 10, pl. 1, figs. 18-23.

Collarette present, extending to anterior fins, and exceptionally wide. Head large. Lateral fields small. Muscles broad and thick. Body firm, broad, opaque, and nearly of uniform width from in front of ventral ganglion to tail-septum. Anterior fins longer than posterior fins, extending to ventral ganglion. Posterior fins about same width as anterior fins, extending to seminal vesicles. Less than 50 per cent of posterior fin in front of tail-septum. "Vestibular ridge strongly mammillated, terminating externally in a very blunt process." *Corona ciliata* long, commencing in front of eyes and terminating near ventral ganglion. Anterior teeth 4-10, closely set, and with broad bases. Posterior teeth 9-14, long, broad, closely set, and diverging distally. Seizing jaws 5-6. Tail 26-36 per cent of total length.

Sagitta regularis Aida

Aida (1897), p. 18, tab. 3, fig. 1.
Doncaster (1902b), p. 211.
Fowler (1906), p. 18, pl. 2, figs. 55-58.
Ritter-Záhony (1909b), fig. 7.

The similarity of this species to *S. neglecta* has already been considered in detail. Ritter-Záhony (1909b) says: "Bei gut erhaltenen Individuen ist allerdings die ausserordentlich mächtig entwickelte Collarette mit den stark vorspringenden Tasthügeln das beste Erkennungsmerkmal, haüfig bemerkt ich jedoch, dass sie infolge der Konservierung verloren gegangen oder stark geschrumpft war."

Collarette conspicuous, extending to anterior fins. Head small. Muscles broad and stout. Body firm, opaque, and of about the same width from ventral ganglion to seminal vesicles. Anterior fins shorter and narrower than posterior fins, extending nearly to ventral ganglion. Posterior fins widest behind tail-septum, and extending to seminal vesicles. Less than 50 per cent of posterior fin in front of tail-septum. Anterior teeth 2-4. Posterior teeth 2-7. Seizing jaws 6-9. Tail 28-40 per cent of total length.

Sagitta pulchra Doncaster

Doncaster (1902b), p. 213.
Fowler (1906), p. 17, pl. 2, figs. 49-54.

Collarette present. Body very transparent, slender, and firm. Widest about one-half to three-fourths distance from head to tail-septum, tapering gradually forward, and more rapidly backward. Anterior fins longer and narrower than posterior fins, the anterior fourth consisting of epidermic thickening with but few rays. Posterior fins widest at, or behind, tail-septum, barely extending to seminal vesicles. More than 50 per cent of posterior fin in front of tail-septum. Vestibular ridge with sharp, regular papillae, and provided with a very strong external process. *Corona ciliata* long, commencing between eyes and extending one-half distance from head to ventral ganglion. Anterior teeth 5-10. Posterior teeth 9-15. Seizing jaws 5-7. Tail 18-27 per cent of total length.

Sagitta bedoti Béraneck

Béraneck (1895), p. 137.
Fowler (1906), pp. 6-8, pl. 1, figs. 1-8.

Collarette absent. Head small. Lateral fields large. Muscles strong but narrow. Body firm, transparent, and widest at middle of length, with sudden diminution at tail-septum. Anterior fin longer than posterior fin, extending nearly to ventral ganglion. Posterior fins broader than anterior fins, widest behind tail-septum, and extend to seminal vesicles. Less than 50 per cent of posterior fin in front of tail-septum. Papillae of vestibular ridge regular and acute. External process long and sharp. Anterior teeth 5-13. Posterior teeth 16-32. Seizing jaws 5-7. Tail 21-35 per cent of total length.

Sagitta macrocephala Fowler

Fowler (1905), p. 65, pl. 5, figs. 16-21.

Collarette absent. Head unusually large. Neck narrow and promi-

nent. Lateral fields small. Body slender, firm, opaque, and widest at middle of length. Anterior fins shorter and narrower than posterior fins, never extending to ventral ganglion. Posterior fins about equally divided between body and tail, but usually with more than 50 per cent in front of septum. Vestibular ridge with thick cuticle and provided with irregular papillae, which are fewer in number than posterior teeth. Anterior teeth 5-10. Posterior teeth 12-33. Seizing jaws 9-12, very sharply curved in the distal fourth. Tail 29-41 per cent of total length.

Sagitta gazelle Ritter-Záhony

Ritter-Záhony (1909c), p. 788.

The characters of this species have already been considered in connection with the description of *S. lyra* (pp. 32-39). As the description given by Ritter-Záhony is incomplete, I can add nothing to my former remarks.

Eukrohnia pacifica (Aida)

Aida (1897), pp. 19, 20, tab. 3, fig. 11.
Fowler (1906), p. 24, pl. 3, figs. 81-85.

Collarette absent. Head medium. Neck fairly evident. Body slender, about 5 per cent in width, but broader than in *E. subtilis*. Widest about midway between ventral ganglion and tail-septum, tapering gradually in both directions. Lateral fins arise nearly two-thirds distance from ventral ganglion to tail-septum, and terminate at seminal vesicles. Usually slightly less than 50 per cent of fin in front of tail-septum, its point of greatest width being behind septum. *Corona ciliata* short, clove-shaped, extending onto head but never reaching eyes. Teeth "bayonet-shaped" springing from a narrower neck than in *E. subtilis*, the number varying from 11 to 16. Seizing jaws, 6-9, with back of shaft made up of two curves, the junction of which makes an obtuse angle at a point about one-fourth the length of jaw proximad of tip. Tail 25-41 per cent of total length.

Spadella cephaloptera Busch

Busch (1851), pp. 93-100.
Hertwig (1880), pp. 66-67, taf. 1, fig. 6.
Fowler (1906), p. 34, pl. 3, figs. 95-99.

Collarette massive, widest just behind head, but less than half the width of body. Head medium. Neck evident. Collarette extends to tail-septum, where it becomes continuous with lateral fin. Body firm and opaque. Lateral fin more than five times longer than wide, extending to seminal vesicles. *Corona ciliata* confined to neck, its long axis being transverse to the body and extending over the collarette. Anterior teeth 3-4, irregularly set and blunt, the innermost being very long. Posterior teeth 3-4. Seizing jaws 8-9, slender and slightly saginate. Tail 50 per cent of total length.

PART II. DISTRIBUTION

EXPLANATION OF THE TABLES OF DISTRIBUTION

The data from which the following discussions and conclusions have been derived are printed in full. It is believed that, in connection with other plankton investigations, students of this Marine Biological Station will find the data advantageous for purposes of correlation. It is also probable that other students of distribution, after accumulating observations, may discover important relations suggested in these data.

For convenience the data are arranged in four sections. First, the surface catches are tabulated; second, those hauls made with horizontal closing nets; third, those made with vertical closing nets, and fourth, those made with open vertical nets. Temperature and salinity are not indicated in connection with closing net hauls because, till the present, it has been impossible to operate the water bottle and closing net at even approximately the same time. For records of relation between depth, temperature, and salinity see McEwen (1910). Temperature is recorded in Centigrade, depth in fathoms, and latitude and longitude to one-tenth of one minute measured from Greenwich.

The following symbols are employed to indicate the various nets used in making collections:

A. Surface net 000 XX mesh silk bolting cloth, orifice 97.5 cm. in diameter.

B. Kofoid closing net 000 XX mesh silk bolting cloth, orifice 37.0 cm. in diameter.

C. Nansen closing net 1 XX mesh silk bolting cloth, orifice 109.5 cm. in diameter.

F. Nansen closing net 000 XX mesh silk bolting cloth, orifice 45.2 cm. in diameter.

Method of Counting

If a haul seemed to contain under three hundred individuals of a species they were counted. When the number appeared

greater, the following method was employed. After sorting the species, from sixty to one hundred specimens were removed with forceps and placed on filter paper to allow the fluid to drain off. This sample was then accurately weighed and counted. Dividing this weight by the number of specimens in the sample gave an average individual weight. A second sample was then treated likewise. The mean between the two average weights thus obtained was considered final, and the weight of the entire haul divided by this mean approximated the number of individuals contained. The usual error in this method has been calculated from twenty-five tests and amounts to about 5 per cent. In no instance was it over 10 or under 2 per cent.

TABLE 28

Distribution with Respect to Surface Hauls, Net A.

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day and Duration of haul	Temperature of water	Salinity of water	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. neglecta*	*S. planktonis*
	1904												
216	July 23	9:30 p.m.	.....	.....	32° 35.0	117° 18.8	.....	....	....	....	50	....	....
275	Sept. 17	7:30 a.m.	.....	.....	32° 38.6	117° 24.0	.....	2	....	....	2000	....	....
	1905												
411[1]	Feb. 25	.....	15°.5	.....	32° 40.6	117° 30.0	3500	....	....	1	75	9	....
412[2]	Feb. 25	.....	15°.5	.....	32° 40.6	117° 30.0	3100	4	....	1	64	75	....
473	April 29	.....	16°.5	.....	32° 45.2	117° 23.2	6	....	....	....	6	38	....
	1908												
1415	June 11	2:25 p.m.	.....	.....	32° 55.6	117° 33.0	.....	....	....	....	5	....	....
1416	June 11	2:25 p.m.	.....	.....	32° 55.6	117° 33.0	1	....	....	....	1620	....	....
1417	June 12	12:00–12:20 p.m.	16°.5	33.380	32° 51.0	117° 34.0	.....	....	....	....	3	....	....
1418	June 12	10:00–10:20 a.m.	16°.4	33.404	32° 51.0	117° 34.0	.....	....	....	....	11	....	....
	1907												
1422	Nov. 2	5:00– 5:30 p.m.	.....	.....	32° 32.0	117° 17.0	.....	....	....	....	9	....	1
1423	Nov. 3	8:25– 8:45 a.m.	.....	.....	32° 39.0	117° 14.2	.....	....	....	....	135	....	....
1426	Nov. 3	9:20– 9:40 a.m.	.....	.....	32° 38.1	117° 14.1	.....	....	....	10	1250	....	....

[1] The single specimen of *Spadella draco* was obtained in this haul.

[2] Hauls 411, 412, and 473 began some time before 6:00 a.m. and ended sometime before 10:00 a.m.

TABLE 28—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day and Duration of haul	Temperature of water	Salinity of water	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. neglecta*	*S. planktonis*
	1908												
1438	June 16	11:00–11:40 a.m.	18°.5	33.558	32° 46'.9	117° 31'.8	.....	....	....	....	25	....	....
1444	June 17	12:30– 1:00 p.m.	16°.5	.....	33° 0'.1	117° 50'.0	.....	....	....	....	25	....	....
1448	June 17	2:40– 3:20 p.m.	16°.5	.....	32° 59'.5	117° 43'.6	.....	....	....	....	50	....	....
1452	June 17	3:26– 3:39 p.m.	16°.5	33.432	33° 0'.1	117° 38'.9	.....	....	....	....	1	....	....
1455	June 18	10:45–11:20 a.m.	16°.5	.....	32° 57'.8	117° 46'.0	.....	....	....	....	20	....	....
1460	June 18	1:40– 2:20 p.m.	17°.1	33.630	32° 49'.8	117° 46'.0	.....	....	....	....	20	....	....
1465	June 19	7:45– 8:25 a.m.	17°.8	33.693	32° 57'.7	117° 22'.7	.....	....	....	3	20	....	....
1471	June 19	10:20–10:40 a.m.	17°.5	34.069	32° 59'.0	117° 22'.3	.....	2	....	20	10	....	....
1489	June 25	8:25– 9:15 a.m.	18°.6	33.630	32° 55'.2	117° 21'.4	.....	....	2	7	127	....	....
1505	June 26	12:25–12:50 p.m.	20°.0	33.617	32° 38'.8	117° 29'.9	.....	....	....	....	16	....	....
1509	June 27	5:58– 6:15 a.m.	18°.6	33.670	32° 54'.1	117° 21'.0	.....	....	....	....	72	....	....
1512	June 27	6:20– 6:45 a.m.	18°.9	.....	32° 54'.1	117° 21'.0	.....	....	....	....	60	....	....
1530	July 2	11:40–12:00 a.m.	17°.5	.....	32° 58'.3	118° 14'.7	.....	....	2	....	.....	....	....
1535	July 8	7:30– 7:50 a.m.	18°.9	.....	32° 21'.9	118° 19'.1	.....	2	....	....	3	....	....
1559	July 18	6:20– 6:30 a.m.	16°.5	.....	32° 24'.2	119° 6'.2	.....	....	....	....	2000	....	....
1560	July 18	7:20– 8:00 a.m.	16°.5	33.457	32° 24'.2	119° 6'.2	.....	....	....	....	527	....	1
1562	July 18	8:00– 9:00 p.m.	19°.5	33.630	32° 47'.9	117° 51'.8	.....	....	....	....	75	....	....
1568	July 21	2:45– 3:13 p.m.	22°.3	33.630	32° 49'.6	117° 28'.8	.....	....	....	....	5	....	....
1579	July 22	7:30– 7:50 p.m.	20°.8	33.704	32° 51'.5	117° 21'.4	.....	....	....	2	563	....	....

TABLE 28—*Continued*

Data concerning each haul								Number of specimens obtained						
Haul number	Date		Time of day and Duration of haul	Temperature of water	Salinity of water	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. neglecta*	*S. planktonis*
	1908													
1582	July	22	8:10– 8:35 p.m.	20°.5	33.646	32° 51′.9	117° 21′.6	.....	....	....	7	600	....	....
1585	July	23	4:30– 4:53 a.m.	19°.8	33.646	32° 51′.5	117° 22′.0	.....	....	....	....	15	....	....
1591	July	23	7:50– 8:12 p.m.	22°.2	33.646	32° 51′.7	117° 20′.7	.....	....	....	5	200	....	....
1594	July	23	8:20– 8:42 p.m.	20°.5	33.574	32° 51′.8	117° 22′.0	.....	....	....	....	150	....	....
1597	July	24	4:26– 4:46 a.m.	20°.5	33.549	32° 51′.4	117° 22′.2	.....	....	....	....	75	....	....
1600	July	24	4:58– 5:18 a.m.	20°.5	33.603	32° 51′.5	117° 22′.6	.....	....	....	....	3	....	....
1605	Aug.	26	7:00– 7:20 p.m.	19°.3	.....	32° 18′.8	117° 27′.1	.....	....	....	1	35	....	....
	1909													
1634	Feb.	19	5:50– 6:20 a.m.	13°.6	.....	32° 44′.5	117° 39′.3	.....	....	....	....	250	....	....
1643	June	15	11:45 a.m.–12:45 p.m.	18°.2	.....	32° 52′.3	117° 31′.8	.....	....	....	....	5	....	....
1650	June	16	5:10– 5:55 p.m.	18°.6	.....	32° 51′.7	117° 32′.4	.....	....	....	....	15	....	....
1653	June	16	6:10– 6:45 p.m.	18°.6	33.616	32° 51′.4	117° 32′.1	.....	....	....	....	40	....	....
1655	June	16	6:55– 7:20 p.m.	.....	.....	32° 51′.0	117° 31′.9	.....	....	....	....	75	....	....
1657	June	16	7:25– 8:00 p.m.	18°.4	33.670	32° 51′.0	117° 31′.9	.....	....	....	....	5100	....	....
1659	June	17	5:00– 6:00 p.m.	18°.4	.....	32° 51′.3	117° 16′.7	.....	....	....	....	13	....	....
1661	June	17	6:45– 7:30 p.m.	18°.4	.....	32° 51′.3	117° 16′.7	.....	....	....	....	550	....	....
1673	June	21	6:00– 6:25 p.m.	18°.0	33.563	32° 51′.8	117° 30′.4	.....	....	....	....	30	....	....
1680	June	21	7:00– 7:35 p.m.	15°.9	33.563	32° 52′.0	117° 32′.0	.....	....	....	....	3600	....	....
1682	June	21	7:40– 8:15 p.m.	15°.9	33.563	32° 52′.1	117° 33′.1	.....	....	....	....	80	....	....

TABLE 28—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day and Duration of haul	Temperature of water	Salinity of water	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. neglecta*	*S. planktonis*
	1909												
1686	June 22	4:00– 5:00 a.m.	17°.9	33.574	32° 53′.2	117° 36′.5	.....	1	....	....	1600	....	....
1689	June 22	5:16– 6:11 a.m.	17°.9	33.563	32° 52′.8	117° 35′.7	.....	....	....	....	475	....	....
1698	June 23	6:10– 6:50 a.m.	17°.2	33.574	32° 52′.0	117° 30′.0	.....	....	....	....	20	....	....
1703	June 23	7:00– 8:55 a.m.	17°.2	33.534	32° 52′.0	117° 30′.0	.....	....	....	....	105	....	....
1712	June 24	5:05– 6:15 p.m.	17°.5	33.561	32° 52′.0	117° 30′.0	.....	....	....	....	191	....	....
1716	June 24	6:20– 7:05 p.m.	17°.5	33.563	32° 52′.0	117° 30′.0	.....	....	....	1	50	....	....
1719	June 24	7:15– 8:23 p.m.	17°.2	34.009	32° 52′.0	117° 30′.0	.....	....	....	....	55	....	....
1728	June 25	5:10– 6:10 p.m.	17°.7	33.534	32° 52′.0	117° 30′.0	.....	....	....	....	72	....	....
1731	June 25	6:15– 7:00 p.m.	17°.7	33.776	32° 52′.0	117° 30′.0	.....	....	....	....	50	....	....
1734	June 25	7:03– 7:40 p.m.	17°.7	33.534	32° 52′.0	117° 30′.0	.....	....	....	....	103	....	....
1738	June 25	7:45– 8:41 p.m.	17°.6	33.549	32° 52′.0	117° 30′.0	.....	....	....	14	105	....	....
1744	June 28	5:00– 6:20 p.m.	19°.2	33.648	32° 52′.0	117° 30′.0	.....	....	....	....	2	....	....
1751	June 28	7:15– 8:00 p.m.	19°.0	33.603	32° 52′.0	117° 30′.0	.....	....	....	....	155	....	....
1754	June 28	8:10– 8:50 p.m.	19°.0	33.603	32° 52′.0	117° 30′.0	.....	....	....	....	1100	....	....
1767	June 30	4:00– 4:25 p.m.	19°.1	33.630	32° 50′.1	118° 3′.1	.....	....	....	....	1	....	....
1772	July 1	7:55– 8:23 a.m.	16°.7	33.603	32° 52′.5	118° 21′.5	.....	....	....	1	9	....	....
1784	July 2	4:50– 5:11 a.m.	18°.7	33.648	32° 49′.0	118° 21′.0	.....	....	....	....	618	....	....
1791	July 2	6:37– 7:00 a.m.	16°.6	33.681	32° 48′.0	118° 27′.0	.....	....	....	....	41	....	....
1815	July 7	4:50– 5:35 a.m.	19°.0	33.811	32° 52′.0	117° 30′.0	.....	....	....	....	46	....	....

TABLE 28—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day and Duration of haul	Temperature of water	Salinity of water	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. neglecta*	*S. planktonis*
	1909												
1836	July 7	7:55– 8:25 p.m.	19°.4	33.648	32° 52′.3	117° 20′.0	.....	....	....	....	330	....	....
1850	July 9	3:30– 4:15 a.m.	18°.8	33.690	32° 52′.3	117° 20′.0	.....	....	....	....	270	....	....
1854	July 9	4:20– 5:15 a.m.	18°.8	33.571	32° 52′.3	117° 20′.0	.....	....	....	....	6	....	....
1860	July 9	5:18– 6:25 a.m.	18°.6	33.589	32° 52′.3	117° 20′.0	.....	....	....	....	4	....	....
1868	July 9	7:03– 7:36 p.m.	19°.0	33.589	32° 52′.3	117° 20′.0	.....	....	....	....	10	....	....
1872	July 9	7:40– 8:15 p.m.	18°.8	33.630	32° 52′.3	117° 20′.0	.....	....	....	....	4300	....	....
1875	July 9	8:45–11:35 p.m.	19°.0	33.630	32° 52′.3	117° 20′.0	.....	....	....	....	275	....	....
1883	July 10	12:55– 4:28 a.m.	19°.2	33.762	32° 53′.0	117° 18′.0	.....	....	....	....	85	....	....
1888	July 10	4:35– 5:20 a.m.	19°.1	33.690	32° 53′.0	117° 18′.0	.....	....	....	....	132	....	....
1892	July 10	5:25– 5:55 a.m.	19°.2	33.747	32° 53′.0	117° 18′.0	.....	....	....	....	15	....	....
1902	Sept. 1	5:46– 6:06 a.m.	16°.6	.....	32° 40′.0	117° 30′.0	.....	....	....	....	12	....	....
1910	Sept. 2	5:52– 6:13 a.m.	18°.4	33.874	32° 37′.2	118° 37′.2	.....	....	....	....	2	....	....
1915	Sept. 2	2:05– 2:27 p.m.	18°.2	33.675	32° 28′.0	119° 3′.0	.....	....	....	....	8	....	....
1920	Sept. 3	6:00– 6:37 a.m.	19°.5	33.856	32° 48′.5	118° 20′.3	.....	....	....	....	3	....	....
1931	Sept. 3	6:14– 6:43 p.m.	20°.1	33.793	32° 53′.9	117° 53′.2	.....	....	....	....	170	....	....
1941	Nov. 2	6:00– 6:20 a.m.	17°.5	33.964	32° 52′.0	117° 30′.0	.....	....	....	3	.....	....	....
1954	Nov. 2	12:04–12:26 p.m.	18°.8	33.901	32° 52′.0	117° 30′.0	.....	....	....	....	50	....	....
	1910												
1991	Feb. 17	6:20– 7:15 a.m.	13°.1	33.621	32° 39′.5	117° 31′.5	.....	....	....	....	16	....	....

TABLE 28—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day and Duration of haul	Temperature of water	Salinity of water	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. neglecta*	*S. planktonis*
	1910												
1998	Feb. 17	7:30– 9:15 a.m.	13°.4	33.684	32° 39′.5	117° 31′.5	.....	....	....	....	12	....	....
2010	Feb. 18	2:52– 4:25 p.m.	14°.2	33.811	32° 51′.2	117° 31′.5	.....	....	....	....	55	....	....
2014	Feb. 18	4:50– 6:15 p.m.	13°.8	33.567	32° 51′.2	117° 31′.5	.....	....	....	....	220	....	....
2024	Feb. 18	6:57– 7:54 p.m.	13°.8	33.558	32° 51′.2	117° 31′.5	.....	....	....	....	165	....	....
2028	March 15	1:12– 1:50 p.m.	15°.4	33.486	32° 40′.4	117° 31′.0	.....	....	....	....	3	....	....
2033	March 15	2:00– 2:43 p.m.	15°.8	33.558	32° 40′.4	117° 31′.0	.....	....	....	....	3	....	....
2064	March 16	6:00– 6:55 p.m.	.....	.....	32° 40′.4	117° 31′.2	.....	....	....	....	63	....	....
2070	March 17	1:30– 2:18 p.m.	14°.7	33.783	32° 50′.0	117° 30′.0	.....	....	....	....	3	....	....
2078	March 17	2:20– 3:34 p.m.	14°.7	33.738	32° 50′.0	117° 30′.0	.....	....	....	....	4	....	....
2082	March 17	3:40– 4:30 p.m.	17°.7	33.666	32° 50′.6	117° 29′.2	.....	....	....	....	13	....	....
2085	March 17	4:45– 5:10 p.m.	14°.6	33.522	32° 50′.6	117° 29′.2	.....	....	....	....	7	....	....
2096	March 17	6:15– 6:50 p.m.	14°.6	33.747	32° 50′.6	117° 29′.2	.....	....	....	....	125	....	....
2101	March 17	6:55– 7:30 p.m.	14°.6	33.549	32° 50′.6	117° 29′.2	.....	....	....	....	472	....	....
2109	April 19	8:30– 9:45 a.m.	16°.4	33.738	32° 23′.0	117° 20′.0	.....	....	....	....	5	....	....
2123	April 20	4:45– 5:30 a.m.	.....	.....	32° 22′.3	117° 19′.0	.....	....	....	....	10	....	....
2126	April 20	5:38– 6:10 a.m.	15°.8	33.603	32° 21′.6	117° 18′.5	.....	....	....	....	31	....	....
2136	April 21	4:40– 5:05 a.m.	16°.2	33.802	32° 23′.5	117° 22′.2	.....	....	....	....	224	....	....
2145	April 21	5:15– 5:35 a.m.	16°.2	.....	32° 23′.5	117° 20′.0	.....	....	....	....	140	....	....

TABLE 29

Data concerning Surface Hauls containing no Chaetognatha.

Haul number	Date		Time of day and Duration of haul	Temperature of water	Salinity of water	North Latitude	West Longitude
	1908						
1432	June	15	10:30–10:50 a.m.	18°.9	.....	32° 39′.3	117° 30′.1
1436	June	16	9:30– 9:50 a.m.	16°.5	33.534	32° 48′.5	117° 34′.4
1478	June	23	4:45– 5:05 p.m.	18°.3	.....	32° 41′.4	117° 30′.3
1499	June	25	3:45– 4:10 p.m.	19°.5	.....	32° 51′.4	117° 21′.5
1518	June	30	9:50–10:05 a.m.	18°.5	.....	32° 54′.4	117° 21′.5
1588	July	23	5:05– 5:30 a.m.	19°.7	33.617	32° 52′.1	117° 20′.2
	1909						
1660	June	17	6:00– 6:45 p.m.	18°.4	.....	32° 51′.3	117° 16′.7
1662	June	17	7:30– 8:00 p.m.	18°.4	.....	32° 51′.3	117° 16′.7
1667	June	19	8:45– 9:15 a.m.	.....	.....	32° 37′.1	117° 14′.5
1695	June	23	4:55– 6:00 a.m.	17°.6	33.574	32° 52′.0	117° 30′.0
1747	June	28	6:35– 7:11 p.m.	19°.0	33.603	32° 52′.0	117° 30′.0
1759	June	29	4:30– 4:50 a.m.	18°.6	33.571	32° 52′.0	117° 30′.0
1763	June	29	5:40– 6:35 a.m.	18°.7	33.735	32° 52′.0	117° 30′.0
1779	July	1	10:52 a.m.–12:40 p.m.	20°.4	33.778	32° 52′.6	118° 21′.5
1796	July	2	9:38–10:11 a.m.	17°.6	33.531	32° 44′.5	117° 53′.5
1800	July	2	12:45– 1:36 p.m.	20°.55	33.747	32° 41′.2	117° 32′.3
1804	July	2	4:23– 4:50 p.m.	20°.35	33.720	32° 40′.0	117° 26′.0
1810	July	2	6:15– 7:05 p.m.	20°.2	33.630	32° 40′.0	117° 26′.0
1812	July	7	4:10– 4:45 a.m.	.....	.....	32° 52′.0	117° 30′.0
1819	July	7	5:40– 6:35 a.m.	19°.0	33.690	32° 52′.0	117° 30′.0
1823	July	7	6:40– 7:36 a.m.	19°.0	33.690	32° 52′.0	117° 30′.0
1826	July	7	6:00– 7:00 p.m.	19°.2	33.733	32° 53′.[illegible]	117° 20′.0
1832	July	7	7:04– 7:50 p.m.	.....	.....	32° 53′.3	117° 20′.0
1837	July	8	10:20–11:05 a.m.	.....	.....	32° 51′.3	117° 18′.8
1864	July	9	6:15– 7:00 p.m.	19°.0	33.589	32° 52′.3	117° 20′.0
1881	July	10	11:35 p.m.–12:45 a.m.	18°.9	33.648	32° 52′.3	117° 20′.0
1906	Sept.	1	12:40–12:50 p.m.	18°.5	33.829	33° 0′.0	118° 41′.2
1967	Nov.	3	5:05– 5:45 p.m.	18°.0	33.865	32° 54′.1	117° 30′.1
1981	Nov.	5	11:50 a.m.–12:42 p.m.	17°.6	33.666	32° 40′.6	117° 30′.3
	1910						
2039	March	15	2:47– 4:03 p.m.	16°.2	33.774	32° 40′.4	117° 31′.0
2044	March	15	4:25– 5:20 p.m.	15°.6	33.585	32° 40′.4	117° 31′.0
2049	March	16	1:10– 1:50 p.m.	15°.5	33.675	32° 39′.2	117° 27′.0
2054	March	16	2:30– 3:22 p.m.	15°.4	33.693	32° 40′.4	117° 31′.2
2062	March	16	4:40– 5:50 p.m.	.....	.....	32° 40′.4	117° 31′.2
2091	March	17	5:30– 6:10 p.m.	14°.6	33.549	32° 50′.6	117° 29′.2
2114	April	19	9:55–10:45 a.m.	16°.5	33.657	32° 20′.9	117° 18′.5

TABLE 30

Distribution with Respect to Horizontal Closing Net Hauls.

Data concerning each haul								Number of specimens obtained						
Haul number	Date		Time of day and Duration of haul	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1909													
1821	July	7	7:05– 7:35 a.m.	B	5	32° 52.0	117° 30.0	....	....	....	2	....	....	....
1827	July	7	6:40– 7:03 p.m.	C	5	32° 52.3	117° 20.0	....	....	....	190	....	....	....
1873	July	9	8:16– 8:26 p.m.	B	5	32° 52.3	117° 20.0	....	1	....	5	....	....	....
1879	July	10	12:27–12:37 a.m.	B	5	32° 52.3	117° 20.0	....	....	....	6	....	....	....
1889	July	10	5:19– 5:30 a.m.	B	5	32° 53.0	117° 18.0	....	....	....	1	....	....	....
1792	July	2	6:50– 7:10 a.m.	C	6	32° 48.0	118° 27.0	....	....	....	65	....	....	....
1798	July	2	1:10– 1:35 p.m.	C	6	32° 41.2	117° 32.3	....	....	....	14	....	....	....
1885	July	9	6:53– 7:03 p.m.	B	7	32° 52.3	117° 20.0	....	....	....	7	....	....	....
1833	July	7	7:05– 7:52 p.m.	C	9	32° 52.3	117° 20.0	....	....	....	12	....	....	....
1878	July	10	12:12–12:23 a.m.	B	10	32° 52.3	117° 20.0	....	....	15	.....	....	....	....
1886	July	10	5:03– 5:15 a.m.	B	10	32° 53.0	117° 18.0	....	....	....	15	....	....	....
1872	Nov.	3	5:44– 5:54 p.m.	B	10	32° 54.1	117° 30.0	....	....	....	2	....	....	....
1789	July	2	6:36– 6:48 a.m.	C	12	32° 48.0	118° 27.0	....	....	....	18	....	....	....
1807	July	2	6:10– 6:35 p.m.	C	12	32° 40.0	117° 26.0	....	....	....	17	....	....	....
1834	July	7	7:51– 8:20 p.m.	B	15	32° 52.3	117° 20.0	....	....	....	7	....	....	....
1839	July	8	11:45–11:55 a.m.	B	15	32° 52.0	117° 19.2	....	....	....	30	....	....	....
1845	July	8	1:57– 2:10 p.m.	B	15	32° 52.3	117° 18.6	....	....	....	7	....	....	....
1852	July	9	4:55– 5:07 a.m.	B	15	32° 52.3	117° 20.0	....	....	....	23	....	....	....

TABLE 30—*Continued*

Data concerning each haul								Number of specimens obtained						
Haul number	Date		Time of day and Duration of haul	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1909													
1862	July	9	6:38– 6:48 p.m.	B	15	32° 52.3	117° 20.0	....	....	....	17	....	....	....
1877	July	9	11:55 p.m.–12:05 a.m.	B	15	32° 52.3	117° 20.0	....	....	4	6	....	....	....
1885	July	10	4:45– 4:55 a.m.	B	15	32° 53.0	117° 18.0	....	....	....	14	....	....	....
1923	Sept.	3	8:32– 8:40 a.m.	B	15	32° 49.4	118° 20.3	....	....	....	3	....	....	....
1668	June	19	9:05– 9:30 a.m.	C	20	32° 37.1	117° 14.5	....	....	....	500	....	....	....
1770	July	1	7:25– 7:45 a.m.	C	20	32° 28.1	118° 18.3	....	....	....	9	....	....	....
1785	July	2	5:00– 5:23 a.m.	C	20	32° 49.0	118° 21.0	....	....	....	35	....	....	....
1802	July	2	4:23– 4:50 p.m.	C	20	32° 40.0	117° 26.0	....	....	....	18	....	....	....
1971	Nov.	3	5:33– 5:43 p.m.	B	20	32° 54.1	117° 30.0	....	....	....	14	....	....	....
1748	June	28	7:10– 7:35 p.m.	B	25	32° 52.0	117° 30.0	....	5	9	1	....	....	....
1761	June	29	5:55– 6:20 a.m.	B	25	32° 52.0	117° 30.0	....	1	....	1	....	....	....
1788	July	2	6:00– 6:35 a.m.	C	25	32° 48.0	118° 27.0	....	1	....	.....	....	....	....
1793	July	2	8:38– 8:48 a.m.	C	25	32° 44.5	117° 55.5	....	....	....	20	....	....	....
1797	July	2	12:45– 1:05 p.m.	C	25	32° 41.2	117° 32.3	....	....	....	84	....	....	....
1851	July	9	4:33– 4:43 a.m.	B	25	32° 52.3	117° 20.0	....	....	7	2	....	....	....
1870	July	9	7:55– 8:05 p.m.	B	25	32° 52.3	117° 20.0	....	....	....	4	....	....	....
1876	July	9	11:30–11:45 p.m.	B	25	32° 52.3	117° 20.0	....	4	....	.....	....	....	....
1984	Nov.	5	12:42–12:52 p.m.	B	25	32° 40.6	117° 30.3	....	....	1	.....	....	....	....
1844	July	8	1:35– 1:45 p.m.	B	30	32° 52.5	117° 19.0	....	....	....	15	....	....	....

TABLE 30—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day and Duration of haul	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1909												
1861	July 9	6:18– 6:30 p.m.	B	30	32° 52.3′	117° 20.0′	....	....	5	.....	....	....	....
1858	July 9	6:10– 6:23 a.m.	B	35	32° 52.3′	117° 20.0′	....	....	2	1	....	....	....
	1908												
1476	June 21	11:00 a.m.	B	50	32°	117°	1	....	....	300	1	....	....
1603	July 24	12:33–12:41 p.m.	B	50	32° 51.4′	117° 18.2′	....	....	....	70	....	....	....
	1909												
1708	June 24	4:58– 5:15 p.m.	C	50	32° 52.0′	117° 30.0′	....	....	....	3	....	....	....
1760	June 29	5:25– 5:50 a.m.	B	50	32° 52.0′	117° 30.0′	....	....	3	.....	....	....	....
1816	July 7	5:30– 5:55 a.m.	B	50	32° 52.0′	117° 30.0′	....	1	....	.....	....	....	....
1828	July 7	6:55– 7:20 p.m.	B	50	32° 52.3′	117° 20.0′	....	....	....	3	....	....	....
1846	July 8	2:10– 2:20 p.m.	B	50	32° 52.1′	117° 18.4′	....	....	....	1	....	....	....
1857	July 9	5:05– 5:18 a.m.	B	50	32° 52.3′	117° 20.0′	....	....	6	.....	....	....	....
1866	July 9	7:15– 7:25 p.m.	B	50	32° 52.3′	117° 20.0′	....	....	....	5	....	....	....
1929	Sept. 3	2:53– 3:12 p.m.	B	50	32° 53.6′	117° 53.7′	4	....	....	.....	....	....	....
1966	Nov. 3	5:20– 5:28 p.m.	B	50	32° 53.6′	117° 30.0′	....	....	6	.....	....	....	....
	1908												
1575	July 22	10:44–10:55 a.m.	B	75	32° 52.8′	117° 31.8′	....	....	76	65	....	....	....
	1909												
1928	Sept. 3	2:17– 2:40 p.m.	B	75	32° 55.2′	117° 54.8′	....	8	....	.....	....	....	....

TABLE 30—*Continued*

Data concerning each haul								Number of specimens obtained						
Haul number	Date		Time of day and Duration of haul	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1909													
1688	June	22	4:40– 5:20 a.m.	C	100	32° 52.6	117° 36.0	....	4	4	.....	....	....	....
1691	June	23	4:55– 5:20 a.m.	C	100	32° 52.0	117° 30.0	....	....	20	.....	....	....	....
1714	June	24	6:25– 6:45 p.m.	B	100	32° 52.0	117° 30.0	....	1	9	.....	....	....	....
1725	June	25	4:45– 5:15 p.m.	C	100	32° 52.0	117° 30.0	....	....	....	2	....	....	....
1757	June	29	4:40– 4:50 a.m.	B	100	32° 52.0	117° 30.0	....	1	....	2	....	....	....
1813	July	7	4:25– 5:00 a.m.	B	100	32° 52.0	117° 30.0	....	2	12	.....	....	....	....
1869	July	9	7:35– 7:45 p.m.	B	100	32° 52.3	117° 20.0	....	....	....	5	....	....	....
1947	Nov.	2	7:16– 7:30 a.m.	B	100	32° 50.0	117° 30.0	....	....	3	.....	....	....	....
1965	Nov.	3	4:40– 4:50 p.m.	B	100	32° 53.2	117° 30.0	....	....	5	.....	....	....	....
1979	Nov.	5	11:51–12:00 a.m.	B	100	32° 40.6	117° 30.3	....	1	30	.....	....	....	....
1736	June	25	8:12– 8:32 p.m.	B	110	32° 52.0	117° 30.0	....	....	....	.....	....	2	....
1927	Sept.	3	1:22– 1:39 p.m.	B	125	32° 52.6	117° 55.9	....	11	21	.....	1	....	....
1756	June	28	8:50– 9:16 p.m.	B	150	32° 52.0	117° 30.0	....	....	2	.....	....	....	....
1735	June	25	7:34– 7:54 p.m.	B	160	32° 52.0	117° 30.0	....	1	16	.....	....	....	....
1690	June	22	6:35– 6:50 a.m.	B	200	32° 51.9	117° 35.6	....	....	10	.....	....	....	....
1700	June	23	7:25– 7:45 a.m.	B	200	32° 52.0	117° 30.0	....	....	4	.....	....	....	....
1745	June	28	6:28– 6:48 p.m.	B	200	32° 52.0	117° 30.0	....	....	3	.....	....	....	....
1926	Sept.	3	12:21–12:52 p.m.	B	200	32° 52.1	117° 57.0	....	13	46	.....	1	....	3
1948	Nov.	2	7:43– 8:03 a.m.	B	200	32° 50.0	117° 30.0	....	2	13	.....	....	....	....

TABLE 30—*Continued*

Number of specimens obtained								Data concerning each haul						
Haul number	Date		Time of day and Duration of haul	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1909													
1964	Nov.	3	4:20– 4:35 p.m.	B	200	32° 53.2′	117° 30.0′	....	....	40	.....	....	....	....
1978	Nov.	5	11:25–11:35 a.m.	B	200	32° 40.6′	117° 30.3′	....	1	29	.....	....	....	1
1732	June	25	6:53– 7:14 p.m.	B	220	32° 52.0′	117° 30.0′	....	1	13	.....	....	....	....
	1908													
1557	July	17	1:45– 2:30 p.m.	B	250	32° 24.2′	119° 6.2′	....	50	24	.....	....	....	....
	1909													
1729	June	25	6:13– 6:35 p.m.	B	250	32° 52.0′	117° 30.0′	....	2	17	.....	....	....	....
1963	Nov.	3	2:53– 3:13 p.m.	B	300	32° 52.0′	117° 30.0′	....	....	....	.....	....	2	....
	1908													
1550	July	16	11:45 a.m.–12:40 p.m.	B	350	32° 49.2′	118° 14.9′	....	2	....	.....	3	....	....
1567	July	21	1:06– 1:19 p.m.	B	350	32° 49.2′	118° 14.9′	....	....	2	.....	....	2	....

TABLE 31

Data concerning Horizontal Closing Net Hauls containing no Chaetognatha.

Haul number	Date		Time of day and Duration of haul	Net used	Depth in fathoms	North Latitude	West Longitude
	1909						
1842	July	8	12:55– 1:05 p.m.	B	5	32° 52′.5	117° 19′.5
1843	July	8	1:17– 1:28 p.m.	B	5	32° 52′.5	117° 19′.2
1856	July	9	5:27– 5:40 a.m.	B	5	32° 52′.3	117° 20′.0
1808	July	2	6:43– 7:05 p.m.	C	6	32° 40′.0	117° 26′.0
1865	July	9	6:53– 7:08 p.m.	B	7½	32° 52′.3	117° 20′.0
1841	July	8	12:40– 1:00 p.m.	C	7–8	32° 52′.2	117° 19′.3
1805	July	2	4:55– 5:25 p.m.	C	8	32° 40′.0	117° 26′.0
1820	July	7	6:32– 6:55 a.m.	B	10	32° 52′.0	117° 30′.0
1840	July	8	12:35–12:45 p.m.	B	10	32° 52′.2	117° 19′.3
1855	July	9	5:12– 5:22 a.m.	B	10	32° 52′.3	117° 20′.0
1794	July	2	9:52–10:09 a.m.	C	12	32° 44′.5	117° 53′.5
1801	July	2	1:38– 2:00 p.m.	C	12	32° 41′.2	117° 32′.3
1817	July	7	6:05– 6:25 a.m.	B	25	32° 52′.0	117° 30′.0
1830	July	7	7:25– 7:45 p.m.	B	25	32° 52′.3	117° 20′.0
1884	July	10	4:25– 4:40 a.m.	B	25	32° 53′.0	117° 18′.0
1930	Sept.	3	3:22– 3:37 p.m.	B	25	32° 53′.9	117° 53′.2
1944	Nov.	2	6:21– 6:41 a.m.	B	25	32° 52′.0	117° 30′.0
	1908						
1572	July	22	9:16– 9:29 a.m.	B	30	32° 51′.4	117° 33′.3
	1909						
1970	Nov.	3	5:20– 5:30 p.m.	B	30	32° 54′.1	117° 30′.0
	1908						
1542	July	9	6:45– 7:00 p.m.	B	50	33° 0′.2	118° 31′.3
1620	Aug.	29	10:30–11:14 a.m.	B	50	29° 8′.6	118° 16′.8
	1909						
1704	June	23	8:55– 9:17 a.m.	B	50	32° 52′.0	117° 30′.0
1739	June	25	8:41– 9:00 p.m.	B	50	32° 52′.0	117° 30′.0
1752	June	28	7:42– 8:05 p.m.	B	50	32° 52′.0	117° 30′.0
1909	Sept.	1	12:55– 1:25 p.m.	C	50	33° 0′.0	118° 41′.2
1946	Nov.	2	6:50– 7:05 a.m.	B	50	32° 52′.0	117° 30′.0
1980	Nov.	5	12:11–12:35 p.m.	B	50	32° 40′.6	117° 30′.3
	1908						
1621	Aug.	30	10:52–11:01 a.m.	B	100	29° 8′.6	118° 17′.5
	1909						
1753	June	28	8:15– 8:38 p.m.	B	100	32° 52′.0	117° 30′.0
1824	July	7	6:30– 6:50 p.m.	B	100	32° 53′.3	117° 20′.0
1684	June	21	9:20– 9:45 p.m.	B	150	32° 53′.0	117° 32′.7
1701	June	23	8:15– 8:25 a.m.	B	150	32° 52′.0	117° 30′.0
1764	June	29	6:30– 7:10 a.m.	B	150	32° 52′.0	117° 30′.0
	1908						
1576	July	22	12:33–12:46 a.m.	B	200	32° 55′.6	117° 30′.4
	1909						
1683	June	21	8:10– 8:40 p.m.	B	250	32° 52′.8	117° 33′.2
1699	June	23	6:35– 7:00 a.m.	B	250	32° 52′.0	117° 30′.0
	1908						
1578	July	22	1:52– 2:07 p.m.	B	300	32° 57′.6	117° 28′.8
	1909						
1726	June	25	5:00– 5:55 p.m.	B	300	32° 52′.0	117° 30′.0
1925	Sept.	3	10:41–11:11 a.m.	B	300	32° 51′.2	117° 59′.1

TABLE 32

Distribution with Respect to Vertical Closing Net Hauls.

Data concerning each haul							Number of specimens obtained						
Haul number	Date 1910	Time of day[1]	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
2022	Feb. 18	8:00 p.m.	C	25– 10	32° 51.2	117° 31.5	....	....	.....	4	....	....	....
2043	March 15	4:18 p.m.	C	25– 10	32° 40.4	117° 31.0	....	....	.....	6	....	....	....
2047	March 15	5:26 p.m.	C	25– 10	32° 40.4	117° 31.0	....	....	13	....	....	....	....
2077	March 17	3:24 p.m.	C	25– 10	32° 50.0	117° 30.0	....	....	.....	2	....	....	....
2104	March 17	7:34 p.m.	C	25– 10	32° 50.0	117° 30.0	....	....	20	4	....	....	....
1990	Feb. 17	7:03 a.m.	C	50– 25	32° 39.4	117° 29.9	....	....	1	....	....	....	....
2020	Feb. 18	7:35 p.m.	C	50– 25	32° 51.2	117° 31.5	....	....	1	....	....	....	....
2042	March 15	4:05 p.m.	C	50– 25	32° 40.4	117° 31.0	....	....	.....	15	....	....	....
2060	March 16	4:20 p.m.	C	50– 25	32° 40.4	117° 31.2	....	....	.....	10	....	....	....
2076	March 17	3:14 p.m.	C	50– 25	32° 50.0	117° 30.0	....	....	4	28	....	....	....
2100	March 17	7:24 p.m.	C	50– 25	32° 50.0	117° 30.0	....	....	12	4	....	....	....
2105	April 19	8:37 a.m.	F	50– 25	32° 23.3	117° 19.9	....	....	.....	3	....	....	....
2118	April 20	3:00 a.m.	F	50– 25	32° 23.3	117° 20.0	....	....	.....	2	....	....	....
2130	April 21	3:07 a.m.	F	50– 25	32° 23.5	117° 22.8	....	....	9	....	....	....	....
2141	April 21	6:12 a.m.	F	50– 25	32° 23.5	117° 20.9	....	....	.....	3	....	9	....
2038	March 15	3:52 p.m.	C	75– 50	32° 40.4	117° 31.0	2	....	78	....	....	....	....
2059	March 16	4:08 p.m.	C	75– 50	32° 40.4	117° 31.2	....	....	.....	43	....	....	....
2075	March 17	2:59 p.m.	C	75– 50	32° 50.0	117° 30.0	....	....	12	73	....	....	....
2099	March 17	6:53 p.m.	C	75– 50	32° 50.0	117° 30.0	....	....	78	....	....	....	....
2106	April 19	8:54 a.m.	F	75– 50	32° 22.8	117° 19.6	....	....	4	....	....	....	....
2119	April 20	3:15 a.m.	F	75– 50	32° 23.0	117° 19.9	....	1	4	....	....	....	....

TABLE 32—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day[1]	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1910												
2131	April 21	3:21 a.m.	F	75– 50	32° 23.5	117° 22.7	....	....	5	....	....	....	....
2142	April 21	6:23 a.m.	F	75– 50	32° 23.5	117° 20.6	....	....	9	....	....	....	9
2037	March 15	3:35 p.m.	C	100– 75	32° 40.4	117° 31.0	....	3	40	....	....	....	....
2058	March 16	3:55 p.m.	C	100– 75	32° 40.4	117° 31.2	....	....	11	34	....	....	....
2074	March 17	2:43 p.m.	C	100– 75	32° 50.0	117° 30.0	....	1	263	....	....	....	....
2095	March 17	6:37 p.m.	C	100– 75	32° 50.0	117° 30.0	....	1	128	10	....	....	....
2107	April 19	9:09 a.m.	F	100– 75	32° 22.5	117° 19.4	....	....	.....	3	....	....	....
2120	April 20	3:36 a.m.	F	100– 75	32° 22.8	117° 19.5	....	....	.....	2	....	....	....
2132	April 21	3:36 a.m.	F	100– 75	32° 23.5	117° 22.6	....	....	.....	3	....	....	....
1996	Feb. 17	8:27 a.m.	C	150–100	32° 39.6	117° 31.5	....	1	14	....	....	....	....
2018	Feb. 18	6:57 p.m.	C	150–100	32° 23.3	117° 20.0	....	....	44	....	....	....	....
2036	March 15	3:00 p.m.	C	150–100	32° 40.4	117° 31.0	....	....	206	....	....	....	....
2057	March 16	3:37 p.m.	C	150–100	32° 40.4	117° 31.2	....	3	170	34	....	....	....
2073	March 17	2:23 p.m.	C	150–100	32° 50.0	117° 30.0	....	....	156	....	....	....	....
2094	March 17	6:17 p.m.	C	150–100	32° 50.0	117° 30.0	1	....	165	....	....	....	....
2108	April 19	9:32 a.m.	C	150–100	32° 21.9	117° 19.0	....	....	15	....	....	....	....
2133	April 21	3:54 a.m.	F	150–100	32° 23.5	117° 22.5	....	....	3	....	....	....	....
2144	April 21	6:50 a.m.	F	150–100	32° 23.5	117° 20.0	....	....	.....	3	....	....	....
1997	Feb. 17	9:35 a.m.	C	200–150	32° 39.5	117° 31.5	....	5	168	....	....	....	2
2017	Feb. 18	6:30 p.m.	C	200–150	32° 51.2	117° 31.5	....	....	15	....	....	....	....
2032	March 15	2:28 p.m.	C	200–150	32° 40.4	117° 31.0	....	11	248	....	....	....	....

TABLE 32—*Continued*

Data concerning each haul							Number of specimens obtained						
Haul number	Date	Time of day[1]	Net used	Depth in fathoms	North Latitude	West Longitude	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1910												
2053	March 16	3:08 p.m.	C	200–150	32° 40′.4	117° 31′.2	....	3	345	....	....	1	....
2069	March 17	2:02 p.m.	C	200–150	32° 50′.0	117° 30′.0	....	10	400	....	....	....	1
2090	March 17	5:58 p.m.	C	200–150	32° 50′.0	117° 30′.0	....	3	100	....	....	....	....
2112	April 19	9:55 a.m.	C	200–150	32° 20′.5	117° 18′.1	....	1	49	....	1	....	....
2122	April 20	4:33 a.m.	F	200–150	32° 22′.4	117° 19′.4	....	....	2	....	....	....	....
2134	April 21	4:20 a.m.	F	200–150	32° 23′.5	117° 22′.4	....	....	24	....	....	....	....
2001	Feb. 17	10:06 a.m.	C	250–200	32° 39′.0	117° 31′.4	....	2	140	1	2	4	....
2031	March 15	2:01 p.m.	C	250–200	32° 40′.4	117° 31′.0	....	3	190	....	3	....	3
2052	March 16	2:41 p.m.	C	250–200	32° 40′.4	117° 31′.2	....	6	240	....	1	1	10
2068	March 17	12:57 p.m.	C	250–200	32° 50′.0	117° 30′.0	....	9	715	....	....	....	11
2089	March 17	5:37 p.m.	C	250–200	32° 50′.0	117° 30′.0	....	5	129	....	....	....	1
2113	April 19	10:28 a.m.	C	250–200	32° 20′.4	117° 18′.0	....	1	21	....	....	....	....
2149	April 21	7:36 a.m.	F	250–200	32° 23′.5	117° 20′.0	....	....	2	....	....	1	....
2048	March 16	1:20 p.m.	C	300–250	32° 40′.4	117° 31′.2	....	6	264	....	....	....	....
2067	March 17	1:10 p.m.	C	300–250	32° 50′.0	117° 30′.0	....	5	478	....	2	1	2
2081	March 17	4:20 p.m.	C	300–250	32° 50′.0	117° 30′.0	....	11	316	....	6	....	3
2139	April 21	5:19 a.m.	F	300–250	32° 23′.5	117° 21′.6	....	....	1	....	....	....	....

[1] Hauls were all made at approximately the same velocity and therefore the time consumed or duration of haul varied from 2 to 5 minutes, depending upon distance of haul. For this reason the duration of each haul is not given.

TABLE 33

Data Concerning Vertical Closing Net Hauls Containing no Chaetognatha.

Haul number	Date	Time of day	Net used	Depth in fathoms	North Latitude	West Longitude
	1910					
1994	Feb. 17	7:17 a.m.	C	75– 50	32° 39′.6	117° 30′.5
1995	Feb. 17	8:07 a.m.	C	100– 75	32° 40′.0	117° 32′.0
2143	April 21	6:35 a.m.	F	100– 75	32° 23′.5	117° 20′.5
2121	April 20	3:59 a.m.	F	150–100	32° 22′.5	117° 19′.4
2135	April 21	4:47 a.m.	F	250–200	32° 23′.5	117° 22′.3
2027	March 15	1:32 p.m.	C	300–250	32° 40′.4	117° 31′.0

TABLE 34

Distribution with Respect to Open Vertical Net Hauls.

Data concerning each haul							Number of specimens obtained							
Haul number	Date	Time of day	Net used	Depth in fathoms	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1904													
236	Aug. 9	7:10 a.m.	A	2–0	32° 38.7′	117° 22.3′	.....	....	....	.....	250	1	....	....
217	July 23	9:30 p.m.	A	5–0	32° 35.0′	117° 18.8′	.....	....	....	.....	700	....	....	....
218	July 23	10:00 p.m.	A	5–0	32° 35.0′	117° 18.8′	.....	....	....	.....	800	....	....	....
234	Aug. 8	9:30 a.m.	A	5–0	32° 34.1′	117° 19.7′	1	....	....	.....	375	....	....	....
219	July 23	9:30 p.m.	A	10–0	32° 35.0′	117° 18.0′	.....	....	....	.....	2100	....	....	....
235	Aug. 8	10:00 a.m.	A	10–0	32° 34.1′	117° 19.7′	5	....	....	.....	2500	....	....	....
251	Aug. 27	7:10 a.m.	A	10–0	32° 36.5′	117° 30.6′	1	....	....	.....	471	....	....	....
274	Sept. 17	7:00 a.m.	A	10–0	32° 38.6′	117° 24.0′	3500	....	....	.....	2700	....	....	....
	1908													
1571	July 22	8:15 a.m.	A	10–0	32° 50.6′	117° 33.8′	.....	....	....	.....	5	....	....	....
1574	July 22	10:15 a.m.	A	10–0	32° 53.3′	117° 32.3′	.....	....	....	.....	1	....	....	....
	1910													
2023	Feb. 18	8:08 p.m	C	10–0	32° 51.2′	117° 31.5′	.....	....	....	.....	3	....	....	....
	1908													
1570	July 22	8:00 a.m.	B	20–0	32° 50.1′	117° 34.0′	.....	....	....	.....	10	....	....	....
	1909													
1838	July 8	11:05 a.m.	A	20–0	32° 51.3′	117° 18.8′	.....	....	....	.....	25	....	....	....
	1910													
2117	April 20	2:47 a.m.	F	25–0	32° 23.3′	117° 20.0′	.....	....	....	.....	6	....	....	....
2129	April 21	2:57 a.m.	F	25–0	32° 23.5′	117° 23.2′	.....	....	....	2	.....	....	....	....
2140	April 21	5:39 a.m.	F	25–0	32° 23.5′	117° 21.0′	.....	....	....	.....	5	....	....	....

TABLE 34—*Continued*

Data concerning each haul							Number of specimens obtained							
Haul number	Date	Time of day	Net used	Depth in fathoms	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1905													
468	April 22	6:00 a.m.	A	45–0	32° 34.9	117° 16.1	10	1	....	.....	400	....	....	....
	1904													
263	Sept. 10	6:30 a.m.	A	50–0	32° 35.0	117° 20.8	.....	....	....	.....	3200	....	....	....
	1909													
1677	June 21	6:20 p.m.	C	50–0	32° 51.7	117° 29.7	.....	....	....	.....	50	....	....	....
	1907													
1393	June 24	7:00 a.m.	A	60–0	32° 53.2	117° 17.2	.....	....	....	.....	30	....	....	....
1398	July 3	10:00 a.m.	A	75–0	32° 53.6	117° 17.4	1	....	....	.....	300	....	....	....
1402	July 9	9:00 a.m.	A	75–0	32° 53.3	117° 18.3	.....	....	....	.....	400	....	....	....
	1909													
1848	July 9	3:50 a.m.	B	75–0	32° 52.3	117° 20.0	.....	....	3	6	10	....	....	....
	1907													
1387	June 17	7:00 a.m.	A	80–0	32° 53.0	117° 18.3	.....	....	....	.....	15	....	....	....
	1904													
262	Sept. 10	6:00 a.m.	A	90–0	32° 35.0	117° 20.8	.....	....	....	.....	1200	....	....	....
	1908													
1495	June 25	11:00 a.m.	A	100–0	32° 55.2	117° 21.4	.....	....	....	.....	1000	....	....	....
	1904													
175	July 12	8:30 a.m.	A	105–0	32° 34.1	117° 19.7	.....	....	....	.....	50	....	....	....

TABLE 34—*Continued*

Data concerning each haul							Number of specimens obtained							
Haul number	Date	Time of day	Net used	Depth in fathoms	North Latitude	West Longitude	*S. enflata*	*S. hexaptera*	*S. lyra*	*S. serratodentata*	*S. bipunctata*	*S. planktonis*	*E. hamata*	*E. subtilis*
	1905													
462	April 15	6:00 a.m.	A	110–0	32° 45′.3	117° 27′.2	1	4	....	1	80	....	....	....
	1908													
1508	June 27	5:58 a.m.	A	150–0	32° 54′.1	117° 21′.0	.....	....	12	48	43	2	....	....
1524	July 1	12:15 p.m.	A	150–0	33° 11′.3	118° 8′.1	.....	....	....	.....	20	....	....	....
	1904													
143	July 5	10:00 a.m.	A	200–0	32° 40′.1	117° 26′.5	.....	....	....	.....	8	....	....	....
	1908													
1492	June 25	10:10 a.m.	A	210–0	32° 55′.2	117° 21′.4	.....	1	5	20	75	3	....	....
1494	June 25	11:00 a.m.	A	210–0	32° 55′.2	117° 21′.4	.....	....	7	10	25	....	....	....
1516	June 30	9:20 a.m.	A	250–0	32° 54′.4	117° 21′.5	.....	2	9	10	40	....	....	....
	1910													
2088	March 17	5:11 p.m.	C	250–0	32° 50′.0	117° 30′.0	.....	....	8	382	2	3	1	3
	1908													
1483	June 24	10:00 a.m.	A	284–0	33° 5′.0	117° 29′.8	.....	....	....	6	20	....	....	....
1468	June 19	9:35 a.m.	A	290–0	32° 58′.8	117° 22′.8	1	....	7	60	6	2	1	....
	1909													
1717	June 24	7:15 p.m.	B	300–0	32° 51′.0	117° 30′.0	.....	....	1	13	8	....	1	....
	1908													
1527	July 2	11:20 a.m.	A	500–0	32° 58′.3	118° 14′.7	.....	1	2	60	10	2	20	....

GENERAL DISCUSSION OF THE PROBLEMS OF DISTRIBUTION

Any interpretation of the data contained in the above tables depends on what we regard as adequate methods of collecting. The numerous methods employed may be distinguished according to the purpose in collecting. If we desire to study a single species from some morphological, physiological, or other special standpoint, or if we desire to study the number and range of species over extensive areas, we will employ any apparatus adapted to collecting the material. If, however, we desire to study quantitative relations among species, or the abundance of each in any region, we must employ specially constructed apparatus and collect with respect to the conditions affecting this abundance.

Most single expeditions have endeavored to increase our knowledge of the number and range of species over extensive areas. For instance, the monumental achievements of the "Challenger" expedition consist in having collected and described an enormous number of species representing nearly every class of animals. To determine the general environment of the species obtained from each locality, the hydrographic and meteorological conditions were investigated. The knowledge thus acquired is exceedingly valuable but, owing to the immense region explored, it is necessarily lacking in detail. The methods of collecting employed, while adequate for purposes of preliminary exploration, did not obtain sufficient data to permit interpretations respecting the abundance of each species collected. Such interpretations depend entirely on more special and detailed methods of collecting.

These special methods have been mainly developed under the auspices of the "Kiel Commission" by Hensen, Lohmann, Apstein, and other German investigators. They deserve much credit for originating the methods and inventing valuable apparatus for collecting plankton and analyzing the chemical and physical conditions of the sea. They have calculated filtration capacities, and coefficients of correction for a variety of nets, and have materially increased our mathematical and experimental knowledge concerned in quantitative estimates of plankton. Any

one acquainted with Hensen's (1895) "Methodik der Untersuchung" knows how excellently this difficult and laborious work has been done.

From these important researches the "Kiel school" has drawn conclusions of vast significance which, however, are based on insufficient data. One illustration is enough. On the basis of 167 hauls made during the early spring of 1895 in the North Sea, Hensen and Apstein (1897) estimated that the surface waters contained 157,000,000,000 fish eggs. From a knowledge of the average number of eggs annually produced by each species these authors state that the number of mature food fishes in the North Sea may be estimated. As pointed out by Herdman (1906) this estimate is based on one successful haul (only 158 of the 167 hauls made contained fish eggs) for each 3,465,968,354 square meters, or approximately 133,800 square miles, of the sea. Concerning this estimate Johnstone (1908, p. 168) says: "Such an investigation presents fewer difficulties than are encountered in other quantitative researches." Probably Johnstone (1908) has reference to difficulties in calculating filtration capacities and various coefficients of correction for the nets used, but will even the simplest calculation justify such a "collossal conclusion" when based on only one haul from each 133,800 square miles of the sea?

Obviously the reliability of such results depends on uniformity in distribution of plankton over a large area. Are we warranted in assuming that this uniformity exists? Concerning this Herdman (1906, p. 35) says: "On the West Coast of Scotland I have seen large Copepoda so abundant for a mile or two that they seemed from the deck of a yacht to be dancing in crowds in the water . . . . in a few minutes we passed out of the swarm." Again (p. 36) he says: "In the Red Sea and on several occasions in the Indian Ocean I have seen *Trichodesmium erythraeum* forming a most conspicuous red-brown or tawny yellow-brown scum on the surface of the sea for, it might be, a few hundred yards up to a mile in width, and several or even many miles in length, while the sea at each side of the patch was entirely free from the organism." It is unnecessary to quote the numerous similar instances noted by many naturalists. Their

significance in relation to the conclusions of the "Kiel school" is evident.

The data in this paper contain numerous examples of this lack of uniformity in distribution of the Chaetognatha of the San Diego region. Some of these examples are as follows:

1. On July 18, 1908, two surface hauls, 1559 and 1560, were made with the same net in the region of Cortez Banks at 32° 24′.2 N and 119° 6′.2 W. Haul 1559 was made at 6:20 a.m., lasted 10 minutes, and contained 2,000 specimens of *Sagitta bipunctata.* Haul 1560 was made at 7:20 a.m., lasted 40 minutes, and contained 527 of the same species. The temperature of the water during each haul was 16°.5 C. If, as indicated by the temperature, the current remained uniform during both hauls, then the net filtered four times more water during haul 1560 than during haul 1559. Consequently the number of *S. bipunctata* varied from 15 at 6:20 a.m. to 1 at 7:20 a.m. per unit volume of water.

2. On July 24, 1908, two surface hauls, 1597 and 1600, were made with the same net. The temperature during each haul was 20°.5 C., and the salinity varied from 33.549 during the first haul to 33.603 during the second. Haul 1597 was made at 4:26 a.m. at 32° 51′.4 N and 117° 22′.2 W. Haul 1600 was made at 4:58 a.m., and the position of the "Agassiz" was 0′.1 farther north and 0′.4 farther west. Each haul lasted 20 minutes. Haul 1597 contained 75 and haul 1600, 3 specimens of *S. bipunctata.* Thus the number of specimens varied from 25 to 1 per unit volume of water.

3. On June 17, 1909, two surface hauls, 1659 and 1661, were made with the same net *while the "Agassiz" was tied to its mooring.* Haul 1659 lasted from 5:00 to 6:00 p.m. and contained 13 specimens of *S. bipunctata.* Haul 1661 lasted from 6:45 to 7:30 p.m. and contained 550 specimens of the same species. Unless the current changed between 5:00 and 7:30 p.m., the net filtered one-fourth more water during haul 1659 than during haul 1661 and the number of specimens obtained per unit volume of water would be in the proportion of about 1 to 56. This difference is all the more striking when we consider that two other hauls were made with the same net at the same mooring on the

same evening, one from 6:00 to 6:45 p.m., the other from 7:30 to 8:00 p.m., which did not contain a single Chaetognath, and that the temperature of the water was 18°.4 C. during all four hauls.

4. On June 21, 1909, two surface hauls, 1680 and 1682, were made with the same net, the former at 32° 52'.0 N and 117° 32'.9 W, and the latter 0'.1 farther north and 0'.2 farther west. Haul 1680 began at 7:00 p.m., haul 1682 at 7:40 p.m., and each lasted 35 minutes. The former contained 3600 and the latter 80 specimens of *S. bipunctata.* Thus, within one hour the number of specimens varied from 45 to 1 per unit volume of water.

5. On June 28, 1909, four surface hauls, 1744, 1747, 1751, and 1754, were made with the same net at 32° 52'.0 N and 117° 30'.0 W. Haul 1744 lasted from 5:00 to 5:20 p.m., haul 1747 from 6:35 to 7:11 p.m., haul 1751 from 7:15 to 8:00 p.m., and haul 1754 from 8:10 to 8:50 p.m. The first haul contained 2 specimens of *S. bipunctata,* the second contained none, the third contained 155, and the fourth contained 1100. The temperature of the water was 19°.2 during haul 1744, and the salinity was 33.648 During the other three hauls the temperature was 19.2° and the salinity was 33.603. The number of specimens per unit volume of water bear the proportion of 1 to 0 to 128 to 1100.

6. On July 9, 1909, three surface hauls, 1850, 1854, and 1860, were made with the same net at 32° 52'.3 N and 117° 20'.0 W. The temperature of the water was 18°.8 C. during the first two hauls and 18°.62 during the third. The salinity was 33.690 during haul 1850, 33.570 during haul 1854, and 33.589 during haul 1860. Haul 1850 lasted from 3:30 to 4:15 a.m., haul 1854 from 4:20 to 5:15 a.m., and haul 1860 from 5:18 to 6:25 a.m. The first contained 270 specimens of *S. bipunctata,* the second contained 6, and the third contained 4. From 3:30 to 6:25 a.m. the number of specimens per unit volume of water varied from 135 to 1.

7. This example illustrates the rapid rate with which some physical conditions of the water may change. Surface haul 1868, made on July 9, 1909, from 7:03 to 7:36 p.m. at 32° 52'.3 N and 117° 20'.0 W, contained 10 specimens of *S. bipunctata.* A

second haul, 1872, made with the same net at the same location and lasting from 7:40 to 8:15 p.m. contained 4300 of the same species. In this instance the number of specimens per unit volume of water was approximately 1 to 430 but, during the first haul, the temperature of the water was 19° C. and the salinity 33.589, while during the second haul the temperature was 18°.8 C. and the salinity 33.630. Obviously a change of 0°.2 in temperature and 0.041 in salinity took place within 37 minutes, and these changes possibly involved an alteration in current and other physical conditions of the water.

Other instances might be cited, but enough have been given to show that the surface distribution of *S. bipunctata* is not constant for any length of time even in very small areas. The objection will be made that hydrographic and meteorological conditions change rapidly near the coast but remain constant on the high seas. I doubt the validity of such an objection. In the first place, owing to variations in wind, rain, light, barometric pressure, heat, etc., it is very improbable that hydrographic and meteorological conditions even approach constancy on the high seas. In the second place, some of the above examples show that *S. bipunctata* varied in abundance even when these conditions, so far as known, remained constant during the period within which the contrasted hauls were made.

Hydrographic and meteorological conditons of the region in which collections are made certainly affect the quantity of plankton present, but does this warrant the assumption that *other conditions* do not also affect it? According to Johnstone (1908), who has championed the cause of the "Kiel school," we are justified in making this assumption. He says (p. 157): "The validity of all conclusions as to the general abundance of microscopic life in the sea depends on the truth of the postulate, that wherever in the sea the *physical conditions* [italics mine] are uniform, there also the composition and abundance of the plankton is uniform."

The truth of this postulate depends upon what is implied by the term "physical conditions." Obviously Johnstone does not mean merely physical conditions for, without chemical and

bacterial activity in the sea, plankton could not exist. If "physical conditions" mean *all conditons in the sea affecting the quantity of plankton,* then the postulate, while true, is meaningless, because it reduces to the statement that if all causes are uniform their effects will be uniform. Again, if the term includes only those conditions in the sea *not due to the behavior of organisms,* the postulate is not true, for it is apparent that rate of growth, rate of reproduction, and food-relations of marine fauna and flora do influence the quantity of plankton. Furthermore, the term may imply that physical conditions have a *more significant effect* than other conditions on the quantity of plankton, and that, consequently, we may disregard these other conditions in estimating its abundance. If this is true, the postulate rests on the assumption that the effects of these other conditions are known, for otherwise we could not distinguish *more significant* from *less significant* effects. It is, however, difficult to believe that all effects on the quantity of plankton in an area of 133,800 square miles could be discovered from evidence obtained during one haul. Finally the term may imply that, owing to a *perfect equilibrium* between all conditions affecting the quantity of plankton, knowledge of the effects of some may be regarded as an index to the effects of all. This supposition, however, involves the enormous assumption that such an equilibrium does exist, and this is certainly not justified by the present state of our knowledge.

Evidently the term "physical conditions" lacks meaning in the sense in which it is used, and consequently the above postulate collapses. Therefore, all calculations based upon this postulate necessarily lead to erroneous conclusions.

Any postulate concerning the abundance of plankton that fails to recognize the influence of organisms on this abundance is inadequate. This is well illustrated by the investigations of Herdman, Scott, and Dakin (1910) who have conducted a very extensive, as well as "intensive study of the marine plankton around the south end of the Isle of Mann." After very careful and excellent investigations they conclude (p. 295): "Some organisms show a remarkable regularity in their time of appear-

ance. For example, the nauplii of *Balanus* began to appear on February 22nd in '07, on February 13th in '08, and on February 6th in '09. This is one of the cases where it is clear that the normal sequence of events in the life-history of the organism is the dominant factor in determining the constitution of the plankton at a definite time and place—the periodic reproduction of the *Balanus* causes the nauplii to appear in the plankton at a certain time.'' Again (p. 296): ''Many other swarms of neritic, and especially meroplanktonic, forms (such as crab zoeas and fish eggs) are similarly due to the succession of stages in the life history . . . .'' We are therefore compelled to acknowledge a very definite causal relation between rate of reproduction and variations in the quantity of plankton.

The influence of organisms on the abundance of plankton is illustrated further, and from quite a different standpoint, by the effects of ''red-water'' due to *Gonyaulax,* on various marine animals, which is discussed by Torrey (1902) in an article entitled ''An unusual occurrence of Dinoflagellata on the California Coast.' He says (p. 187): ''It was first noticed on July 7 as a red streak off the mouth of San Pedro Harbor. During the next few days it approached the shore, changing its shape and dividing into several patches, each many acres in extent. . . . The 'red-water' extended for two hundred miles at least along the coast, from the region of Santa Barbara to San Diego, and extended several miles to sea.'' On July 20 Torrey noticed a ''sickening odor'' arising from the ''red-water,'' and during the next few days he found the following animals on the beach, which were either dead or debilitated. Several hundred *Trachostoma arenata,* many smelts, *Petrolisthes cinctipes,* and *Cancer antennaius,* great numbers of *Hippa analoga,* a number of *Tevila crassatelloides,* and several *Mylobatis californicus, Urolophus halleri,* and octopi. It is also noted that ''wherever it [red-water] was seen the fishermen reported a scarcity of food fishes.'' While most of the animals known to have been affected are not included in what we call plankton, still it is improbable that the plankton was unaffected and, if so, we must acknowledge that the *abundance of plankton may be influenced by the occurrence of large numbers of Gonyaulax.*

It may be claimed that, if the physical and chemical conditions in the "red-water" area had not been what they were *Gonyaulax* would not have occurred in such large numbers and, consequently, the effect of *Gonyaulax* on the abundance of organisms was, after all, due to physical and chemical causes. However, is it not equally true that the effects of the physical and chemical condition of the water on the abundance of organisms were due to *biological causes?* Obviously, had *Gonyaulax* not been present, the physical and chemical condition of the water could not have disabled or killed the animals above mentioned. This tendency so frequently displayed by biologists to resolve biological activities into physical and chemical causes is based on the assumption that an organism is nothing but a physical and chemical complex. While this may be speculatively true, we should only be practically justified in saying that the effect which *Gonyaulax* had on the organisms in the vicinity of San Pedro was entirely due to physical and chemical causes, if we had learned to make this animal out of physical mixtures and chemical compounds.

To adequately estimate the quantity of plankton in a given area of the sea we must consider the influence of biological as well as physical and chemical conditions. In addition to the effects of wind, clouds, fog, rain, snow, ice, light, heat, time of day and season, depth, temperature, salinity, gas-content, and chemical composition of the water, this involves the effects of growth, reproduction, food-relations, and other activities of marine organisms. These factors are more or less correlated, but, as demonstrated by Kofoid (1903), there are variations in the quantity of plankton which are nearly, if not entirely, independent of the particular effects of hydrographic and meteorological conditions. Concerning this Kofoid (1903, p. 503) says: "Somewhat regular alternations of growth and rest, of fission and spore formation, or of parthenogenesis and sexual reproduction, are fundamentally the basis of cyclic movement in [plankton] production. The *amplitudes,* and to some extent the location and duration of the pulses, are plainly affected by the various factors of the environment . . . . by light, temperature, vegeta-

tion, tributary water, various hydrographic factors, and by food supply, and possibly, also, by chemical conditions not directly concerned in nutrition, but the available data fail completely to afford any satisfactory environmental factor or group of factors which stands in correlation, even remotely obvious with this cyclic movement in production. I therefore class this *periodic growth,* these *sexual cycles* which cause volumetric pulses, under the head of internal factors. The element of *periodicity* in itself does not seem to be consequent upon any known external factor.'' On the basis of these facts we must agree with Kofoid (1903) that ''If this cyclic movement in production be characteristic of the plankton generally, freshwater and even marine, it must follow that scattered and irregular collections, or those at intervals exceeding a week or at most a fortnight, may fail entirely to give adequate representation of the course of plankton production or relative fertility of a body of water. Chronological series throughout the whole seasonal range of climatic conditions and at close intervals—of one week or less—are necessary for any accurate delineation of production and fertility of water by the plankton method.'' This is obviously a laborious, time-consuming, and costly method, but it seems to be the only accurate one by which *definite* conclusions concerning the quantitative distribution of plankton can be obtained.

Before concluding these remarks on the problems of distribution, it is well to emphasize the importance of closing nets in obtaining definite knowledge concerning the vertical distribution of plankton. Their importance has been recognized by many investigators such as Chun, Peterson, Agassiz, Hensen, Apstein, Cori, Bergert, Bruce, Giesbrecht, Albert I of Monaco, and Kofoid, through whose researches and inventions the closing net has been developed to its present state of efficiency. However, excepting the Conseil International, ''Siboga,'' Biscayan, and a few other expeditions, most have depended mainly upon open vertical nets for collecting data relative to vertical distribution. Important conclusions have been based on evidence thus obtained, one of which is that the surface Chaetognatha of the Arctic seas would be found, if at all, in the mesoplankton of

temperate and tropical regions. To test this statement I tabulated all accessible data, and discovered that it rested mainly on isolated observations and collections made with open vertical nets.

Data depending on collections made with these nets are of questionable value. This has been noted by Agassiz, Fowler, and others. In discussing the methods of collecting employed by the "Challenger" expedition Agassiz (1888, p. 35) says: "The old practice was employed of dragging for animal forms at intermediate depths by means of a tow-net, which, during the several operations of lowering, dragging, and hauling back remained open; this cannot be regarded as affording acceptable evidence of the habitat of such specimens as were obtained." Again Fowler (1905, p. 81), after pointing out that *S. furcata* was obtained abundantly in closing nets from 150 to 50 fathoms, and that below 200 to 100 fathoms the closing net failed to obtain the species, says: "The specimens recorded in open nets below 100 fathoms were therefore probably caught in the vertical journey upward; an instance of the deceptiveness of the method of open nets." To illustrate further the inadequacy of these nets I have selected the following instances from our data concerning the vertical distribution of the San Diego Chaetognatha.

1. During a period of four years 14 open net hauls were made below 110 fathoms, 15 from a variety of depths between 110 and 25 fathoms, and 13 from above 25 fathoms. Of the 14 hauls from below 110 fathoms 12 contained a total of 668 specimens of *S. serratodentata.* Of the hauls from between 110 and 25 fathoms, one from 75 fathoms contained 6, and one from 25 fathoms 2 specimens of the same species, while in the 13 hauls from above 25 fathoms no specimens were found.

2. During a period of four years *S. lyra* was obtained in 10 out of 21 open net hauls from or below 75 fathoms. During the same period 20 open net hauls were made from above 75 fathoms which failed to obtain the species.

Dare we conclude that *S. serratodentata* does not exist above 25 fathoms, or that *S. lyra* does not exist above 75 fathoms? Obviously such a conclusion is based on the absence of the species

in open net hauls above these depths. However, how do we know that, in the hauls from below 110 fathoms containing *S. serratodentata* and in those from below 75 fathoms containing *S. lyra,* these species were not obtained from 5 or 10 fathoms, or even from the surface? Because they were not near the surface during 20 or even 10,000 hauls made above 25 or 75 fathoms *does not warrant the assumption that they were not near the surface during hauls made from below these depths.* This will be readily acknowledged when we learn that *S. serratodentata* was obtained in 25 out of 148 surface hauls, and in closing net hauls from 10 and 15 fathoms, and that *S. lyra* was obtained in 3 out of 148 surface hauls, and in closing net hauls from 5, 25, and 50 fathoms.

These data mean that conclusions based on open net hauls relate only to the usual manner in which each species is vertically distributed. The significance of this, however, depends on a knowledge of the *unusual* manner in which each is distributed. In other words, a correlation between the vertical distribution of each species and all varying conditions affecting this distribution cannot be made unless we know how the vertical distribution of each species varies. Herein lies the value of the closing net. It enables us to know the exact depth from which every specimen is obtained, and thus supplies knowledge concerning the *unusual* as well as the *usual* manner in which each species is distributed.

The first desideratum, then, for an adequate interpretation of the facts of vertical distribution is the frequent use of closing nets. Used in connection with Ekman's reversing bottles, and accurate deep-sea thermometers, the closing net supplies data the value of which can scarcely be exaggerated. However, in order to solve the problems of vertical distribution, the following precautions are necessary:

1. The area explored must be as small as possible, or the observations will be too scattered for comparison.

2. All conditions affecting the quantity, composition, and distribution of plankton in the region studied must be ascertained, and their effects determined so far as possible.

3. To accomplish this, hauls at all depths should be repeated as often, and under as great a variety of conditions as possible.

4. It is advisable, if not necessary, to plan all collecting with respect to one problem at a time; otherwise the data will be too indefinite to permit accurate conclusions.

5. Emphasis should be laid upon method of collecting rather than on quantity of plankton obtained, for an *ounce* of plankton collected systematically under known conditions, and with respect to definite problems means more than a *ton* otherwise obtained.

In conclusion, all the significant data concerning the distribution of the Chaetognatha so far obtained is condensed into the accompanying table, from which we may provisionally split the order into four groups according to temperature relations. These groups are as follows:

1. Eurythermal species, distributed irrespective of temperature. This group includes *S. bipunctata, S. hexaptera, S. planktonis, S. serratodentata,* and *E. subtilis.*

2. Cold water species, temperature 16°0 to 0°0 or less. This group includes *S. sibogae, S. macrocephala, S. elegans, E. hamata,* and possibly *S. lyra.*

3. Cool water species, temperature 19°0 to 9°5 This group includes *S. decipiens* and *Spadella cephaloptera.*

4. Warm water species, temperature 34°0 to 15°0. This group includes the remaining species, *S. enflata, S. pulchra, S. neglecta, S. regularis, S. bedoti, S. ferox, S. minima, S. tenuis, S. gazelle, S. hispida,* and *Spadella draco.*

It is to be noted that these groups are not sharply defined. *S. lyra,* for instance, while placed in the second group, might be placed in the first, although it has a greater tendency than the others to confine itself to cold water. *S. planktonis,* again is eurythermal regarding vertical distribution, but seems otherwise to be confined to temperate and tropical regions. It is quite possible that, after more extensive collecting with closing nets in the various latitudes, many of the species will be discovered to be eurythermal, with regard to vertical distribution, latitude, or both.

TABLE 35

Distribution of Chaetognatha with Respect to Latitude

Species	Neritic	Oceanic	Northern limit of distribution	Southern limit of distribution	Highest temperature	Lowest temperature	Atlantic Ocean: Arctic: Epiplankton	Atlantic Ocean: Arctic: Mesoplankton	Atlantic Ocean: Sub-Arctic: Epiplankton	Atlantic Ocean: Sub-Arctic: Mesoplankton	Atlantic Ocean: North temperate: Epiplankton	Atlantic Ocean: North temperate: Mesoplankton	Atlantic Ocean: Tropical: Epiplankton	Atlantic Ocean: Tropical: Mesoplankton	Atlantic Ocean: South temperate: Epiplankton	Atlantic Ocean: South temperate: Mesoplankton	Indo-Australian Ocean: South temperate: Epiplankton	Indo-Australian Ocean: South temperate: Mesoplankton	Indo-Australian Ocean: Tropical: Epiplankton	Indo-Australian Ocean: Tropical: Mesoplankton	Pacific Ocean: North temperate: Epiplankton	Pacific Ocean: North temperate: Mesoplankton	Pacific Ocean: Sub-Antarctic: Epiplankton	Pacific Ocean: Sub-Antarctic: Mesoplankton
S. bipunctata[1]	*	*	74° N	28° S	33°6	0°2	*	..	*	....	*	*	*	*	*	....	*	....	*	....	*	....	....	....
S. hexaptera[2]	*	*	70° 30′ N	40° 4′ S	29°0	6°0	*	....	*	....	*	*	*	*	*	...	*	....	*	....	*	*	*	....
S. planktonis[2]	*	*	32° 45′ N	8° 30′ S	27°0	4°7	....	....	....	....	*	*	*	....	....	....	....	....	....	*	*	*	....	....
S. serratodentata[3]	*	*	60° 12′ N	53° S	32°0	6°5	....	....	*	....	*	*	*	....	*	....	....	....	*	....	*	....	*	....
E. subtilis[2]	*	*	60° 12′ N	29° 30′ S	30°8	5°3	....	....	....	....	*	*	*	*	*	...	*	....	*	*	....	*	....	....
S. lyra[4]	*	*	73° N	7° 33′ S	18°6	—1°1	...	*	*	*	*	*	?	?	....	....	....	....	....	....	*	*	....	....
E. hamata[5]	*	*	81° 30′ N	52° S	16°0	—1°1	*	....	*	*	*	*	....	*	....	....	....	....	....	*	....	*	*	....
S. siboga[6]	....	*	27° 4′ N	3° 58′ S	5°5	.....	...	....	....	....	....	—	...	*	....	....	....	....	....	*	....	....	....	....
S. macrocephala[6]	....	*	47° 10′ N	3° 20′ S	10°0	2°5	....	....	....	*	....	*	....	....	....	..	....	....	....	*	....	....	....	....
S. elegans[6]	*	*	81° 14′ N	39° 20′ N	11°0	0°3	*	....	*	....	...	*	....	....	....	....	....	....	....	....	....	....	....	....
S. decipiens[7]	....	*	47° N	.....	11°0	.....	....	....	....	....	....	*	....	....	....	....	....	....	....	....	....	....	....	....
S. cephaloptera[7]	*	....	59° N	38° 10′ N	19°0	9°5	....	....	....	....	*	....	....	....	....	....	....	....	....	....	....	....	....	....
S. enflata[8]	*	*	40° 24′ N	34° 52′ S	32°0	15°5	....	....	....	....	*	....	*	....	*	....	*	...	*	....	*	...	. .	....
S. pulchra[8]	*	....	47° 10′ N	39° S	29°0	14°0	....	....	....	....	....	....	....	....	....	....	....	....	*	....	*	....	....	....
S. neglecta[8]	*	....	35° N	9° S	29°0	15°5	....	....	....	....	....	....	....	....	....	....	....	....	*	....	*	....	....	...
S. regularis[8]	*	....	35° N	6° 30′ S	29°0	21°0	....	....	....	....	....	....	*	....	....	....	....	....	*	....	*	....	....	....
S. bedoti[8]	*	....	35° N	8° 30′ S	29°0	21°0	....	....	....	....	....	....	....	....	....	....	....	....	*	....	*	....	....	....
S. ferox[8]	*	....	6° N	9° S	29°0	.....	....	....	....	....	....	....	....	....	....	....	....	....	*	....	....	....	....	....
S. minima[8]	*	....	41° N	35° N	21°0	19°0	....	....	....	....	*	....	....	....	....	....	....	....	....	....	*	....	....	....
S. tenuis[8]	*	....	18° N	.....	27°0	.....	...	....	....	....	....	....	*	....	....	....	....	....	....	....	....	....	....	....
S. gazelle[8]	....	*	39° S	45° S	.....	.....	...	....	....	....	....	....	....	....	....	....	....	....	*	....	....	....	....	....
S. hispida[8]	*	....	34° 15′ N	25° S	29°0	21°0	...	....	....	....	....	...	*	....	....	....	....	....	*	....	*	....	....	....
E. pacifica[8]	*	....	35° N	7° 30′ S	29°0	.....	....	....	....	...	...	....	*	....	....	....	....	....	*	....	*	....	....	.. .
S. draco[8]	*	*	41° 36′ N	41° 32′ S	29°0	15°5	....	....	....	....	*	....	*	....	*	....	....	....	*	....	*	....	*	....
Total 24	20	14					4	1	6	3	11	10	12	6	6	0	4	0	14	5	14	4	4	0

[1] Eurythermal, euryhyaline, cosmopolitan.
[2] Eurythermal.
[3] Eurythermal, stenobathic.
[4] Cold water, nearly eurythermal.
[5] Cold water, cosmopolitan.
[6] Cold water.
[7] Cool water.
[8] Warm water.

DISCUSSION OF VERTICAL DISTRIBUTION OF THE SAN DIEGO CHAETOGNATHA

In any accurate quantitative consideration of the vertical distribution of a species, all factors affecting the abundance of specimens obtained must be taken into account. Conditions of weather, currents, temperature, and salinity of the water, light, and season are some of these factors. In addition, each net used in collecting filters the water in a unique manner, and even the quantity of plankton obtained in two successive hauls with the same net usually varies. These net factors as well as the environmental factors affect the number of specimens obtained and their exact effect ought to be ascertained.

This problem of quantitative estimates would be much simpler if our engines and cables had permitted an earlier use of vertical closing nets. Being hauled a known distance at a known velocity and against gravitation, the pressure of water on such nets may be calculated and their filtering capacities determined. Furthermore the nets may be rapidly hauled so that the environmental conditions at each depth might be considered constant. These nets have, however, been used for only a few days during February, March, and April of 1910, and while the data obtained are valuable they are not sufficient to permit definite conclusions concerning the vertical distribution of the various species of this region.

Since we are compelled to depend mainly upon data obtained with surface nets and horizontal closing nets, it is almost impossible to estimate the effects of net and environmental factors on the number of specimens obtained in each haul. Obviously the pressure of water is greater on the lower portions of the net, and consequently each area of net surface filters the water at a different rate. The distance the net is hauled and the number, direction, and velocity of currents encountered have a marked effect on the quantity of plankton obtained, and our data supply practically no information regarding these factors. Furthermore, ten to twenty minutes is consumed in hauling, so it is questionable whether or not the environmental conditions of the water can be regarded as constant. For these reasons the amount of

the water filtered during hauls made with different nets, or with the same net at different times, cannot be determined and consequently the number of specimens obtained in respective hauls cannot be accurately compared.

Owing to this impossibility of estimating the value of each horizontal haul, there is apparently only one practicable method of quantitatively considering the vertical distribution of the organisms. If hauls in each depth are numerous and distributed over considerable time, those environmental factors affecting the quantity of plankton obtained will not affect every haul alike. In fact their effects will tend to cancel one another. Now, if we consider the average number of specimens per haul obtained from each depth, we are justified in neglecting the effects of these factors. However, the time consumed during each haul has varied, so it is necessary to standardize the average number of specimens per haul with respect to time. A period of one hour is selected for this purpose. In the following discussion, therefore, the average number of specimens per hour-haul is regarded as the unit for quantitative comparison.

Had the same closing net always been used in collecting, this method, while not absolutely accurate, would yield a fair average estimate of the relative abundance of specimens from each depth. However, the Kofoid closing net and the Nansen closing net were used and this necessitates standardizing the hauls made by one net with those made by the other. While the nets are proportionally similar, the orifice of the former is 37.0 cm. in diameter, and that of the latter 109.5 cm. Since πr^2 equals the area of the orifice, it follows that the portion of a given volume of water filtered by the Kofoid net is to that filtered by the Nansen net as the square of the radius of the former is to that of the latter. In other words, if $r =$ the radius of the Kofoid net, $R =$ that of the Nansen net, $w =$ water filtered by the Kofoid net, and $W =$ that filtered by the Nansen net, then as the nets are proportionally similar, $w : W :: \pi r^2 : \pi R^2$ or $W = \frac{w\,\pi R^2}{\pi r^2} = \frac{w\,R^2}{r^2}$

Now $r = 18.5$ cm. and $R = 54.75$ cm., hence $W = \frac{(54.75)^2}{(18.5)^2} \times w$ or approximately $w \times 8$.

In this calculation it is assumed that both nets have the same size of mesh, but this is not true. The mesh of the Kofoid net is No. 000 and that of the Nansen net No. 1. Obviously, other things being equal, more water will be filtered by the net having the larger mesh, which means that W = less than w × 8. However, owing to the fact that the nets are towed horizontally, the exact effect of this difference in mesh on the amount of water filtered cannot at present be calculated. The number of specimens obtained from each depth by each net are, therefore, uncorrelated and in the following discussion allowance must be made for this fact.

Finally, it is obvious that a surface net of 000 mesh with an orifice of 97.5 cm. in diameter will filter more water than the Kofoid net would if hauled in place of the former. Theoretically the amount of water filtered during a given surface haul would be to that filtered by the Kofoid net as the square of the radius of the former is to that of the latter. In other words, to standardize the number of specimens obtained by the surface net with that obtained by the Kofoid net the number ought to be multiplied by $\frac{(18.5)^2 = \text{radius}^2 \text{ of Kofoid net}}{(48.75)^2 = \text{radius}^2 \text{ of surface net}}$ While this is theoretically required, the resulting fraction 1/7 is found empirically to be far too large. Because this calculation is misleading it seems best to allow for lack of correlation between surface and closing net hauls and regard the average number of specimens obtained per hour from the surface without attempting correction. It will be found that the effects of varying environmental conditions on the manner in which each species is distributed are apparent in spite of this lack of correction.

Although ten species of Chaetognatha were taken from the region of San Diego, lying between 32° 20′ and 33° 30′ N and extending from the coast to 119° W, the region is characterized by an enormous preponderance of one species. Including all hauls from all depths the number of specimens of each species is as follows:

S. bipunctata	51,670
S. enflata	10,127
S. serratodentata	6,575
S. lyra	271
S. neglecta	127

E. hamata	72
E. subtilis	50
S. planktonis	41
S. hexaptera	28
S. draco	1

Owing to the fact that *S. bipunctata* is the most abundant, it is best to consider its manner of distribution first.

VERTICAL DISTRIBUTION OF *SAGITTA BIPUNCTATA.*

Of the total number of this species obtained, 32,601 were taken from the surface, 17,144 in open vertical nets from depths varying from 2 to 500 fathoms, 303 in vertical closing nets from between 150 fathoms and the surface, and 1,322 in horizontal closing nets. Neglecting those obtained with open vertical and vertical closing nets, we find that from July 23, 1904, to April 21, 1910, 148 surface hauls were made, of which 108, or 72 per cent, obtained the 32,601 specimens mentioned. The horizontal closing nets obtained a total of 283 specimens in 7 out of 11 hauls made between 4 and 6 fathoms, 71 in 6 out of 15 hauls between 7 and 12 fathoms, 683 in 13 hauls between 15 and 20 fathoms, 128 in 8 out of 19 hauls between 25 and 35 fathoms, 147 in 6 out of 20 hauls between 40 and 75 fathoms, and 10 in 4 out of 19 hauls between 100 and 150 fathoms. Although 21 hauls were made between 160 and 350 fathoms, the species was not obtained. These data are shown to better advantage in the following table.

TABLE 36

Vertical Distribution of *S. bipunctata* based on Surface and Horizontal Closing Net Hauls

Depth in fathoms	Number of hauls[1]		Number of hours of hauling	Number of specimens		Frequency[2]
	Total	Successful		Total	Per hour	
0	136	96	96.7	29,696	307	70
4–6	11	7	3.3	283	92	64
7–12	15	6	4.6	71	15	40
15–20	13	13	3.5	683	195	100
25–35	19	8	5.3	128	24	42
40–75	20	6	5.7	147	26	30
100–150	19	4	6.5	10	2	21
160–350	21	0	9.0	0	0	0

[1] The durations of hauls 216-1416 are unknown, and they are, therefore, not included in this table.

[2] By frequency is meant the percentage of hauls in which the species appeared without reference to abundance of specimens obtained.

This table marks a distinction between frequency and abundance of *S. bipunctata* at each depth. While it is most frequent in 15-20 fathoms it appears most abundant on the surface. It is fifth in frequency and sixth in abundance in 7-12 fathoms, sixth in frequency and fourth in abundance in 40-75 fathoms, and fourth in frequency and fifth in abundance in 25-35 fathoms. However, in 4-6 and 100-150 fathoms the frequency and abundance are parallel.

We should naturally expect complete parallelism between frequency and abundance, but we find it incomplete. What, then, does this lack of parallelism signify? Is it due to an insufficient number of hauls, to lack of correlation between hauls made with surface and closing nets, to an uneven distribution of hauls with respect to varying environmental conditions, or to a combination of all these influences?

It is obvious that accuracy of the percentage of successful hauls varies with the total number made. Thus the chance of error in the frequency of 100 based upon 13 hauls in 15-20 fathoms is much greater than that in the frequency of 70 based on 136 surface hauls. Had 136 hauls been made in each depth the frequencies noted in the table would undoubtedly be altered.

On the other hand, it was previously stated that the surface net was larger in orifice than the Kofoid closing net, and that the former, therefore, filtered more water per unit length of haul than the latter. Theoretically we estimated that the average number of specimens obtained per hour from the surface ought to be divided by 7 in order to correlate the number with that obtained from each depth by the closing nets. If this were done, however, the number would be reduced to 44, which is much too small to represent the relative number of specimens obtained. We can only be sure that the 307 specimens from the surface should be smaller. Possibly it should be less than 195.

Far more important than either an insufficient number of hauls or lack of correlation between surface and closing net hauls is the fact of their uneven distribution with respect to varying environmental conditions. Variations in temperature, salinity, currents, and light have all doubtless affected the

number of specimens obtained in each haul. Consequently, an average based upon hauls irregularly distributed with respect to these factors is necessarily misleading.

These facts—insufficient number of hauls, lack of correlation between surface and closing net hauls, and irregular distribution of hauls—will explain the disagreement noted between frequency and abundance. However, we may safely conclude:

1. *S. bipunctata* is typically epiplanktonic,[1] occurring between the surface and 150 fathoms.

2. It is rarely found below 75 fathoms.

3. It is most frequent and abundant between the surface and 20 fathoms.

EFFECT OF DAY AND NIGHT ON THE VERTICAL DISTRIBUTION OF *SAGITTA BIPUNCTATA*

It has just been noted that, owing to irregularity in distribution of hauls with respect to varying environmental conditons, the average number of specimens per hour obtained from each depth is misleading. Because our data regarding day and night are more complete than those concerning other environmental factors, it is desirable to consider the influence of this factor on vertical distribution before undertaking to interpret the effects of variations in other factors.

By separating all hauls made between 6 a.m. and 6 p.m. from those made between 6 p.m. and 6 a.m., the *general* effect of day and night on vertical distribution may be considered. Such data are supplied in the following table:

[1] Fowler (1906, p. 47) defines the terms epiplankton and mesoplankton as follows: Epiplankton includes all plankton above the region of 100 fathoms. Mesoplankton includes that between 100 fathoms and to within about 100 fathoms of the bottom.

TABLE 37

Table showing the effect of Day and Night on Distribution of *S. bipunctata*

Depth in fathoms	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
Daylight, or 6 a.m. to 6 p.m.						
0	78	48	54.4	6,902	108	62
4–6	5	3	1.8	81	45	60
7–12	8	2	2.4	20	9	25
15–20	7	7	1.9	581	305	100
25–35	12	5	3.3	121	37	42
40–75	12	4	3.2	139	44	33
100–150	8	2	2.5	3	1	25
Night, or 6 p.m. to 6 a.m.						
0	58	48	42.3	22,794	539	83
4–6	6	4	1.5	202	136	67
7–12	7	4	2.2	51	23	57
15–20	6	6	1.6	102	64	100
25–35	7	3	2.0	7	3	43
40–75	8	2	2.6	8	3	25
100–150	11	2	4.1	7	2	18

This table shows that the ratios between the average number of specimens per hour obtained during the day and the average number obtained during the night are as follows: surface 1 to 5.0; 4-6 fathoms 1 to 3.0; 7-12 fathoms 1 to 2.6; 15-20 fathoms 4.8 to 1; 25-35 fathoms 12 to 1; 40-75 fathoms 14 to 1. Furthermore, the frequency in each depth during the day is to that during the night as 62 to 83 on the surface, 60 to 67 in 4-6 fathoms, 25 to 57 in 7-12 fathoms, 100 to 100 in 15-20 fathoms, 42 to 43 in 25-35 fathoms, and 33 to 25 in 40-75 fathoms. To sum up, these data show that during the night *S. bipunctata* is more frequent and abundant between the surface and 12 fathoms, while it is less so between 15 and 75 fathoms. This probably means that the species migrates in greatest number from all depths below 15 fathoms toward the surface during the night, while during the day it migrates in greatest number from all depths above 15 fathoms toward deeper water.

That there should be lack of parallelism between frequency and abundance in each depth, and why there should be such an abrupt drop in 7-12 fathoms is probably due to the following factors: (1) insufficient number of hauls, (2) impossibility of standardizing the filtering capacities of surface nets with closing nets, and (3) irregular distribution of hauls with respect to the effects of cloudy and foggy days, and moonlit nights. However, whatever effects these factors may have cannot offset the fact that a very evident difference between day and night distribution exists.

The question naturally arises, if this species migrates toward and away from the surface, at what time of day or night does it attain its maximum abundance in each depth? To determine this the specimens obtained from each depth have been segregated into groups according to two-hour periods as indicated in the following table:

TABLE 38

Number of specimens of *S. bipunctata* per hour obtained with respect to Time of Day.

		Equal intervals of time throughout day and night											
Depth		12-2 a.m.	2-4 a.m.	4-6 a.m.	6-8 a.m.	8-10 a.m.	10-12 a.m.	12-2 p.m.	2-4 p.m.	4-6 p.m.	6-8 p.m.	8-10 p.m.	10-12 p.m.
0	sp.	24	166	338	519	169	10	23	19	153	839	383	33
	min.	213	100	646	315	556	420	324	406	852	1154	337	90
4–6	sp.	36	.....	3	80	.....	.....	18	.....	.....	254	30	....
	min.	10	0	24	50	0	0	46	0	0	45	10	0
7–12	sp.	0	.....	41	31	0	.....	0	.....	3	23	.....	....
	min.	11	0	22	35	17	0	52	0	40	97	0	0
15–20	sp.	36	.....	96	27	908	180	.....	32	52	102	17	....
	min.	10	0	45	20	33	10	0	13	37	10	39	0
25–35	sp.	.....	.....	3	1	52	.....	138	0	0	1	.....	0
	min.	0	0	35	113	23	0	40	15	10	67	0	15
40–75	sp.	.....	.....	0	0	0	177	79	1	7	7	0	....
	min.	0	0	63	15	22	22	53	52	25	75	20	0
100–150	sp.	.....	.....	1	0	0	0	4	0	2	6	0	....
	min.	0	0	110	14	10	18	17	10	80	50	84	0

In this table sp. = number of specimens per hour, and min. = number of minutes consumed in hauling. Wherever number of specimens is not recorded no hauls have been made, but wherever hauls were made and no specimens obtained, a 0 indicates this fact.

From this table we learn that *S. bipunctata* appears in maximum abundance between 6 and 8 p.m. on the surface and in 4-6 fathoms, between 4 and 6 a.m. in 7-12 fathoms, between 8 and 10 a.m. in 15-20 fathoms, between noon and 2 p.m. in 25-35 fathoms, and between 10 a.m. and noon in 40-75 fathoms.

Furthermore, the data show two maxima in every depth above 20 fathoms. One occurs between 6 and 10 a.m. and the other between 6 and 8 p.m. Excepting the depth of 100-150 fathoms, only one maximum occurs in each depth below 25 fathoms and that between 10 a.m. and 2 p.m. What does this irregular distribution of maxima signify? Is it merely the effect of chance due to the small amount of hauling, or is some other explanation necessary?

The small number of hauls may have affected this distribution of maxima in some depths, but it will not explain the presence of two maxima on the surface. In correlating the number of *S. bipunctata* on the surface with time of day it is evident that the species increases in abundance from midnight till it reaches a *morning maximum* between 6 and 8 a.m., and after decreasing rapidly to a *minimum* between 10 a.m. and 4 p.m., it increases again till it reaches an *evening maximum* between 6 and 8 p.m. It then gradually decreases to a *midnight minimum.* As most of our collecting was done during June and July, these data teach us that the positions of these maxima approximately correspond to the time of sunrise and sunset. To be more exact, the species attains its morning maximum on the surface within an hour after sunrise, and its evening maximum within an hour after sunset. This indicates that the species migrates toward the surface during twilight and away during bright daylight and darkness.

If this is true, we should expect a greater abundance of specimens on the surface during evening than during morning twilight, for the light *increases* in intensity at dawn while it *decreases* during the evening. Consequently, if the species migrated to the surface during morning twilight its migration would soon be checked owing to the increasing intensity of light, while its migration during the evening would remain unchecked. The fact that the evening maximum is the larger harmonizes entirely with this hypothesis. Why the species should leave the surface so soon after attaining its evening maximum abundance is puzzling. It may be due to the small amount of collecting between 10 p.m. and 4 a.m., to possible

cessation of activity or quiescence of the animals which would cause them to sink, since their specific gravity is greater than that of water, or more probably to the usual relatively high surface temperature (see p. 132).

It is obvious that when light increases in intensity the water nearest the surface is first affected, while when it decreases the reverse is true. During morning twilight, therefore, we should expect the species to ascend first from 4-6 fathoms, later from 7-12 fathoms, and still later from 15-20 fathoms. During evening twilight, however, we should expect migrations first from deeper water. Again, after the morning light becomes too intense, the animals ought to leave the surface first and the succeeding depths later. While our data are inconclusive owing to absence of closing net hauls during many periods of the day, still, when we endeavor to ascertain where the increasing number of specimens on the surface come from and where those leaving the surface go to, the following few facts extracted from table 38 are significant.

1. While an increase from 24 to 338 specimens per hour on the surface took place from midnight to 4-6 a.m. the number in 4-6 fathoms decreased from 36 to 3. Evidence of what happened in 7-12 fathoms is lacking, but in 15-20 fathoms the number increased from 36 to 96. This suggests that the intensity of twilight between 4 and 6 a.m. was sufficient to cause upward migrations from 4-6 but not from 15-20 fathoms.

2. While the number of specimens per hour on the surface increased from 338 between 4 and 6 a.m. to a morning maximum of 519 between 6 and 8 a.m., the number in 4-6 fathoms increased from 3 to 80, while that in 7-12 fathoms decreased from 41 to 31, and that in 15-20 fathoms from 96 to 27. This indicates that the intensity of light after sunrise was sufficient to cause upward migrations from 7-12 and 15-20 fathoms, some specimens reaching the surface while others accumulated in 4-6 fathoms.

3. Combined with a decrease from 519 specimens per hour on the surface between 6 and 8 a.m. to 169 between 8 and 10 a.m. and a decrease in 7-12 fathoms from 31 to 0, is an increase

in 15-20 fathoms from 27 to 908. Does this signify that the intensity of light above 15 fathoms caused the species to migrate downward, while that below 20 fathoms was subdued enough to cause them to migrate upward? The data are too incomplete to warrant such a conclusion, but it is suggested from the fact that the species attained its maximum abundance in 15-20 fathoms at this time.

4. During the next period, 10 a.m. to noon, the number of specimens on the surface decreased from 169 to 10 per hour, and that in 15-20 fathoms decreased from 908 to 180, while the species makes its first appearance in 40-75 fathoms, an average of 177 specimens per hour having been obtained. Owing to lack of collecting in 4-6, 7-12, and 25-35 fathoms at this time, the meaning of this is uncertain. However, it is probable that the intensity of light in 15-20 fathoms is much greater between 10 a.m. and noon than between 8 and 10 a.m., and if so we should expect downward migrations from this depth. Similarly between noon and 2 p.m. the maximum number of specimens was found in 25-35 fathoms and the next most abundant number in 40-75 fathoms.

5. From between 2 and 4, 4 and 6, and 6 and 8 p.m., the number of specimens per hour on the surface increased from 19 to 153 to 889. In 7-12 fathoms it increased from 3 between 4 and 6 p.m. to 23 between 6 and 8 p.m. In 15-20 fathoms it increased from 32 to 75 to 102. We should expect this evening increase to begin first in deeper water and appear last on the surface. Lack of hauling prevents determining this point, but, since this species was not taken below 150 fathoms, its occurrence in maximum abundance in from 25 to 75 fathoms between noon and 2 p.m. and in minimum abundance between 2 and 4 p.m. suggests that upward migration from these depths begins early in the afternoon.

These facts, while they do not prove that intense light causes downward and subdued light upward migrations, certainly point strongly in this direction.

Before leaving this question of the effect of light on the distribution of this species, it is well to consider evidence obtained

from collections made at consecutive times during the same day. This will enable comparison of *actual* instead of *average* numbers of specimens obtained. Because our closing nets were rarely employed during consecutive times in the same depths, such evidence relates entirely to surface collections. Here are a few data.

1. On June 16, 1909, the sun set at 7:10 p.m. Four surface hauls (1650, 1653, 1655, and 1657) were made with the same net. The first lasted from 5:10 to 5:55 p.m., the second from 6:10 to 6:45 p.m., the third from 6:55 to 7:20 p.m., and the fourth from 7:25 to 8:00 p.m. The first haul contained 15, the second 40, the third 75, and the fourth 5100 specimens of *S. bipunctata.* Expressing these numbers with respect to hour-hauls, they are 20, 69, 180, and 8743. In other words, from two hours before until 50 minutes after sunset the number of specimens on the surface *increased 437 times* and, while the number *increased only 9 times during the first 2 hours and 10 minutes, it increased 48 times during the next 40 minutes.*

2. On the next day, June 17, 1909, sunset occurred between 7:10 and 7:11 p.m. From 5 to 6 p.m. one surface haul (1659) was made which contained 13 specimens, and from 6:45 to 7:30 p.m. a second haul (1661) was made which contained 550 specimens. Standardizing these numbers with respect to hour-hauls, we find that *S. bipunctata increased 56 times in abundance from 1 hour and 10 minutes before till 20 minutes after sunset.*

3. On June 21, 1909, the sun set at 7:12 p.m. One surface haul (1673) lasting from 6 to 6:25 p.m. contained 30, and a second haul (1680) lasting from 7 to 7:35 p.m. contained 3600 specimens. In other words, the number when standardized with respect to hour-hauls, *increased 86 times from 47 minutes before till 23 minutes after sunset.*

4. On June 24, 1909, sunset occurred at 7:13 p.m. Haul 1728 lasting from 5:10 to 6:10 p.m. contained 72, haul 1731 lasting from 6:15 to 7:00 p.m. contained 50, and haul 1734 lasting from 7:03 to 7:40 p.m. contained 103 specimens of *S. bipunctata.* Expressing these numbers according to hour-hauls they are 72, 67, and 167. Therefore, the number of specimens on the surface *increased threefold from 13 minutes before till 27 minutes after sunset.*

5. On June 28, 1909, the sun set at 7:12 p.m. Haul 1744 lasting from 5 to 6:20 p.m. contained 2, haul 1751 lasting from 7:15 to 8 p.m. contained 155, and haul 1754 lasting from 8:10 to 8:50 p.m. contained 1100 specimens of *S. bipunctata.* Expressed according to hour-hauls these numbers are 2, 207, and 1650. Here the number on the surface *increased 103 times from 52 minutes before till 48 minutes after sunset, while during the next 50 minutes it increased only 8 times.*

6. On July 9, 1909, sunset occurred at 7:10 p.m. Haul 1868 lasting from 7:03 to 7:36 p.m. contained 10, haul 1872 lasting from 7:40 to 8:15 p.m. contained 4300, and haul 1875 lasting from 8:45 to 11:35 p.m. contained 275 specimens. Expressing these numbers according to hour-hauls they are 18, 7371, and 97. Hence *between 26 minutes and 1 hour and 5 min-*

utes after sunset the number of specimens increased 409 times, and during the next 3 hours it decreased, which suggests that the species attains its maximum abundance within an hour after sunset.

7. On February 8, 1910, the sun set at 5:50 p.m. Three surface hauls (2010, 2014, and 2024) were made. The first, lasting from 2:52 to 4:25 p.m., contained 55, the second, lasting from 4:50 to 6:15 p.m., contained 220, and the third, lasting from 6:57 to 7:54 p.m., contained 165 specimens. Expressed according to hour-hauls these numbers are 35, 155, and 174. This means that *from 3 hours before till 25 minutes after sunset the number increased fourfold, while it increased but slightly during the next hour and 49 minutes.*

8. On March 17, 1910, the sun set at 6:10 p.m. Six surface hauls (2070, 2078, 2082, 2085, 2096, and 2101) were made. They lasted respectively from 1:30 to 2:18 p.m., 2:20 to 3:34 p.m., 3:40 to 4:30 p.m., 4:45 to 5:10 p.m., 6:15 to 6:50 p.m., and 6:55 to 7:30 p.m. They contained respectively 3, 4, 13, 7, 125, and 472 specimens. Expressed according to hour-hauls these numbers are 4, 3, 16, 17, 214, and 809. Hence, *during the period of 4 hours before sunset the number of specimens only quadrupled, while an hour after sunset found the number 13 times larger, and during the succeeding 40 minutes the number quadrupled again.*

The following instances (9 to 13) concern variation in abundance relative to sunrise.

9. On June 27, 1908, sunrise occurred at 4:53 a.m. Two surface hauls (1509 and 1512) were made which lasted respectively from 5:58 to 6:15 a.m. and 6:20 to 6:45 a.m. The former contained 72 and the latter 60 specimens of *S. bipunctata.* Expressed according to hour-hauls these numbers are 306 and 120, which means that the number of specimens on the surface 1 hour and 52 minutes after sunrise *was approximately one-third of that present 30 minutes earlier.* In this instance the first haul began an hour after sunrise, so it is probable that the morning maximum occurred before the time of hauling.

10. On July 24, 1908, the sun rose at 5:08 a.m. Two surface hauls (1597 and 1600) lasted respectively from 4:26 to 4:46 a.m. and 4:58 to 5:18 a.m. The former contained 75 and the latter 3 specimens of *S. bipunctata.* Expressed accordng to hour-hauls the numbers are 229 and 9. This means that *22 minutes before sunrise the animals were 25 times more abundant than at 10 minutes after sunrise.*

11. On July 2, 1909, the sun rose at 4:55 a.m. Haul 1784 lasting from 4:50 to 5:11 a.m. contained 618, and haul 1791 lasting from 6:37 to 7:00 a.m. contained 41 specimens of *S. bipunctata.* Expressed according to hour-hauls the numbers are 1769 and 104. In other words, the number of specimens on the surface *16 minutes after sunrise was 17 times greater than that 1 hour and 40 minutes later.*

12. On July 9, 1909, the sun rose at 4:59 a.m. Three surface hauls (1850, 1854, and 1860) lasting respectively from 3:30 to 4:13 a.m., 4:20 to 5:15 a.m., and 5:18 to 6:25 a.m. were made. The first contained 270, the

second 6, and the third 4 specimens of *S. bipunctata.* Expressed according to hour-hauls the numbers are 360, 6, and 4. Thus, *from 44 minutes before till 16 minutes after sunrise the number of specimens on the surface decreased in the proportion of 90 to 1.*

13. On July 10, 1909, the sun rose at 4:59 a.m. Haul 1888 lasting from 4:35 to 5:20 a.m. contained 132, and haul 1892 lasting from 5:25 to 5:55 a.m. contained 15 specimens of *S. bipunctata.* Expressed according to hour-hauls the numbers are 176 and 30. Hence, *from 39 minutes before till 56 minutes after sunrise the number of specimens on the surface decreased in the proportion of 6 to 1.*

To emphasize the bearing of the thirteen instances just cited I have condensed the data into the following table.

TABLE 39

Actual Distribution of *S. bipunctata* based on Surface Hauls made with the same net during the same days.

Instances cited	Haul number	Time and duration of haul	Number of specimens: Actual	Number of specimens: Per hour	Number of specimens: Ratio	Latitude	Longitude	Temperature	Salinity
		Four hauls made on June 16, 1909. Sunset 7:10 p.m.							
1	1650	5:10–5:55 p.m.	15	20	1	32° 51′.0	117° 31′.9	18°.6	?
	1653	6:10–6:45 p.m.	40	69	3	32° 51′.0	117° 31′.9	18°.6	33.616
	1655	6:55–7:20 p.m.	75	180	9	32° 51′.0	117° 31′.9	?	?
	1657	7:25–8:00 p.m.	5100	8743	437	32° 51′.0	117° 31′.9	18°.4	33.670
		Two hauls made on June 17, 1909. Sunset 7:10 p.m.							
2	1659	5:00–6:00 p.m.	13	13	1	32° 51′.3	117° 16′.7	18°.4	?
	1661	6:45–7:30 p.m.	550	733	56	32° 51′.3	117° 16′.7	18°.4	?
		Two hauls made on June 21, 1909. Sunset 7:12 p.m.							
3	1673	6:00–6:25 p.m.	30	72	1	32° 51′.8	117° 30′.4	18°.0	33.563
	1680	7:00–7:35 p.m.	3600	6171	86	32° 52′.0	117° 32′.9	15°.9	?
		Three hauls made on June 24, 1909. Sunset 7:13 p.m.							
4	1728	5:10–6:10 p.m.	72	72	1	32° 52′.0	117° 30′.0	17°.7	33.534
	1731	6:15–7:00 p.m.	50	67	1	32° 52′.0	117° 30′.0	17°.7	33.776
	1734	7:03–7:40 p.m.	103	167	3	32° 52′.0	117° 30′.0	17°.7	33.534
		Three hauls made on June 28, 1909. Sunset 7:12 p.m.							
5	1744	5:00–6:20 p.m.	2	2	1	32° 52′.0	117° 30′.0	19°.2	33.647
	1751	7:15–8:00 p.m.	155	207	103	32° 52′.0	117° 30′.0	19°.0	33.603
	1754	8:10–8:50 p.m.	1100	1650	825	32° 52′.0	117° 30′.0	19°.0	33.603
		Three hauls made on July 9, 1909. Sunset 7:10 p.m.							
6	1868	7:03–7:36 p.m.	10	18	1	32° 52′.3	117° 20′.0	19°.0	33.589
	1872	7:40–8:15 p.m.	4300	7371	409	32° 52′.3	117° 20′.0	18°.8	33.630
	1875	8:45–11:35 p.m.	275	97	5	32° 52′.3	117° 20′.0	19°.0	33.630

TABLE 39—*Continued*

Actual Distribution of *S. bipunctata* based on Surface Hauls made with the same net during the same days.

Three hauls made on February 18, 1910. Sunset 5:50 p.m.

Instances cited	Haul number	Time and duration of haul	Number of specimens: Actual	Per hour	Ratio	Latitude	Longitude	Temperature	Salinity
7	2010	2:52–4:25 p.m.	55	35	1	32° 51′.2	117° 31′.5	14°.2	33.811
	2014	4:50–6:15 p.m.	220	155	4	32° 51′.2	117° 31′.5	13°.8	33.567
	2024	6:57–7:54 p.m.	165	174	5	32° 51′.2	117° 31′.5	13°.8	33.811
		Six hauls made on March 17, 1910. Sunset 6:10 p.m.							
8	2070	1:30–2:18 p.m.	3	4	1	32° 50′.0	117° 30′.0	14°.7	33.783
	2078	2:20–3:34 p.m.	4	3	1	32° 50′.0	117° 30′.0	14°.7	33.738
	2082	3:40–4:30 p.m.	13	16	4	32° 50′.6	117° 29′.2	14°.7	33.666
	2085	4:45–5:10 p.m.	7	17	4	32° 50′.6	117° 29′.2	14°.6	33.522
	2096	6:15–6:50 p.m.	125	214	53	32° 50′.6	117° 29′.2	14°.6	33.747
	2101	6:55–7:30 p.m.	473	809	202	32° 50′.6	117° 29′.2	14°.6	33.549
		Two hauls made on June 27, 1908. Sunrise 4:53 a.m.							
9	1509	5:58–6:15 a.m.	72	306	3	32° 54′.1	117° 21′.0	18°.6	33.670
	1512	6:20–6:45 a.m.	60	120	1	32° 54′.1	117° 21′.0	18°.9	?
		Two hauls made on July 24, 1908. Sunrise 5:08 a.m.							
10	1597	4:26–4:46 a.m.	75	225	25	32° 51′.4	117° 22′.2	20°.5	33.549
	1600	4:58–5:18 a.m.	3	9	1	32° 51′.5	117° 22′.6	20°.5	33.603
		Two hauls made on July 2, 1909. Sunrise 4:55 a.m.							
11	1784	4:50–5:11 a.m.	618	1769	17	32° 49′.0	118° 21′.0	18°.7	33.647
	1791	6:37–7:00 a.m.	41	104	1	32° 48′.0	118° 27′.0	16°.6	33.681
		Three hauls made on July 9, 1909. Sunrise 4:59 a.m.							
12	1850	3:30–4:15 a.m.	270	360	90	32° 52′.3	117° 20′.0	18°.8	33.690
	1854	4:20–5:15 a.m.	6	6	1	32° 52′.3	117° 20′.0	18°.8	33.571
	1860	5:18–6:25 a.m.	4	4	1	32° 52′.3	117° 20′.0	18°.6	33.589
		Two hauls made on July 10, 1909. Sunrise 4:59 a.m.							
13	1888	4:35–5:20 a.m.	132	176	6	32° 53′.0	117° 18′.0	19°.1	33.690
	1892	5:25–5:55 a.m.	15	30	1	32° 53′.0	117° 18′.0	19°.2	33.747

While the above instances evidence considerable variation in the rates of increase and decrease in abundance, as expressed in the column of ratios, the data demonstrate that marked *decrease occurs about the time of sunrise* and marked *increase directly after sunset.* These facts strikingly confirm our former inference that *S. bipunctata* migrates toward the surface during subdued light and away during intense light and darkness.

To summarize, the facts and inferences respecting light are:

1. During the night this species is most abundant between the surface and 15 fathoms, while during the day it is most abundant below 15 fathoms.

2. The species appears in maximum abundance on the surface and in 4-6 fathoms between 6 and 8 p.m., in 7-12 fathoms between 4 and 6 a.m., in 15-20 fathoms between 8 and 10 a.m., in 25-35 fathoms between noon and 2 p.m., and in 40-75 fathoms between 10 a.m. and noon.

3. In all depths above 20 fathoms the species attains two maxima in abundance during the twenty-four hour day, one occurring between 6 and 10 a.m., and the other between 6 and 8 p.m. Below 20 fathoms only one maximum occurs and that between 10 a.m. and 2 p.m.

4. On the surface the species attains its morning maximum within an hour after sunrise and its evening maximum within an hour after sunset.

5. It is probable that the species migrates toward that depth in which twilight conditions are found.

VARIATION IN DISTRIBUTION OF *S. BIPUNCTATA* DUE TO TEMPERATURE

A variation in surface temperature from 13°1 to 22°3 C. is noted in our data. During February it varied from 13°1 to 15°5, during March from 14°6 to 15°8, during April from 15°8 to 16°4, during June from 15°9 to 19°5, during July from 17°5 to 22°3, during August and September from 16°6 to 19°5, and during November from 17°5 to 18°5. Hauls were not made nor temperatures taken during January, May, October, and December. The variations noted, however, indicate that a minimum

in temperature occurs in the winter months and a maximum in June and July.

These monthly variations in temperature are evidently due to seasonal influences. Consequently, unless some definite period of the year is selected as a basis for determining the effects of variation in temperature on distribution, our interpretations may be misleading. Because the greatest number of collections were made during June and July I have selected these months for this purpose.

While during these months the temperature varied irregularly from 15°.9 to 22°.3 the number of hauls made in water of known temperature are too few to permit considerations of the effects of small changes in temperature on the number of specimens obtained. I have, therefore, segregated the hauls into three groups according to whether the temperature varied from 15°.9 to 17°.5, 17°.6 to 19°.5, or 19°.6 to 21°.5. I have not considered the only hauls (1568 and 1591) made in water having temperatures above 21°.5 because, on the basis of two hauls, it is impossible to eliminate the effects of light on the number of specimens obtained. The following table, therefore, supplies data concerning the relation between temperature and abundance of *S. bipunctata* with respect to the months of June and July.

TABLE 40

Surface Distribution of *S. bipunctata* with Respect to Temperature

Temperature in Centigrade	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
15°.9–17°.5	21	19	12.4	6818	549	91
17°.6–19°.5	53	36	42.8	16274	380	68
19°.6–21°.5	12	7	6.4	1422	222	58

This table shows clearly that the average number of specimens obtained per hour from the surface is greatest when the temperature of the water is least. It also shows that the frequency is greatest when the temperature is least.

It may be objected that, on the basis of so few hauls, the effect of their uneven distribution with respect to intensity of light might account for the results contained in the above table.

This objection would be justified if the greatest number of hauls in water varying from 15°.9 to 17°.5 had been made during morning and evening twilight, while those in water varying from 19°.6 to 21°.5 had been made during intense daylight. However, as frequency means the percentage of hauls in which the species appears without reference to number of specimens obtained, its parallelism with abundance indicates that the hauls were evenly distributed. This is true because, if the species occurred at all, uneven distribution of hauls with respect to light would affect an increase or decrease in abundance but not in frequency. To demonstrate that hauls were evenly distributed, the following table is supplied, which includes only those hauls made during daylight.

TABLE 41

Surface Distribution of *S. bipunctata* between 6 a.m. and 6 p.m.

Temperature in Centigrade	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
15°.9–17°.5	17	15	9.7	3033	312	88
17°.6–19°.5	21	12	14.4	395	27	57
19°.6–21°.5	4	1	3.5	16	25	25

These data show that, during daylight, the species is most abundant and frequent in water having a temperature between 15°.9 and 17°.5. It further shows that the decrease in both frequency and abundance is significantly greater than that found in table 40. This is exactly what would be expected if intensity of light affects the distribution of this species. In the former table, where twilight hauls are included, the effect of higher temperatures in decreasing the abundance of specimens is, to some extent, counteracted by the effect of twilight in increasing it. In table 41, however, only a minimum of twilight hauls are included, and both the effects of more intense light and higher temperatures tend to decrease the abundance.

Still, this greater decrease in abundance and frequency during daylight is possibly affected by an uneven distribution of hauls throughout the various times of day. Our data show that, while three of the four hauls in water having a tempera-

ture between 19°.6 and 21°.5 were made between 10 a.m. and 2 p.m., only three of the twenty-one hauls in water having a temperature between 17°.6 and 19°.5, and six of the seventeen hauls in water having a temperature between 15°.9 and 17°.5 were made during this period. Now we have learned that *S. bipunctata* is on the surface in minimum numbers between 10 a.m. and 2 p.m. It will be interesting, therefore, to see what effect low and high temperatures have on the abundance of the species during this period of greatest light intensity.

TABLE 42

Distribution of *S. bipunctata* during the time of Minimum Abundance

(10 a.m. to 2 p.m.)

Temperature in Centigrade	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
15°.9–17°.5	6	5	2.4	69	29	83
17°.6–19°.5	3	2	2.0	30	15	67
19°.6–21°.5	3	1	3.06	16	5	33

The number of hauls included in this table are too few to determine fully the abundance of specimens with respect to temperature. These data, however, indicate that, even when the species migrates in maximum numbers from the surface, more specimens remain when the temperature is low than when it is high. However, the effect of higher temperatures in decreasing the abundance and frequency of the species is not so great as shown in the preceding table. I believe this means that, when most intense, light has more effect in causing downward migrations from the surface than low temperatures have in causing the species to remain. This cannot be proven but, if true, it suggests that the reverse is also true, namely, that subdued light has more effect in causing upward migrations to the surface than high temperatures have in preventing such migrations. In examining the following two tables evidence of this fact is not wanting.

TABLE 43

Surface Distribution of *S. bipunctata* during Night (6 p.m. to 6 a.m.)

Temperature in Centigrade	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
15°9–17°5	4	4	3.05	3785	1241	100
17°6–19°5	32	24	26.6	15459	581	75
19°6–21°5	8	6	2.9	1404	484	75

TABLE 44

Surface Distribution of *S. bipunctata* during the time of Maximum Abundance (6 to 10 p.m.)

Temperature in Centigrade	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
15°9–17°5	4	4	3.05	3785	1241	100
17°6–19°5	19	14	15.1	12208	808	74
19°6–21°5	8	6	2.9	1404	484	75

In table 43 all four hauls in water having a temperature between 15°9 and 17°5 were made betwen 6 and 10 p.m., while practically half the hauls in water having higher temperatures were made during this period. This means that the 1241 specimens obtained per hour when the temperature was 15°9-17°5 are not strictly comparable with the numbers obtained from water having higher temperatures. While the table shows that abundance and frequency decreases as the temperature increases, the amount of decrease is less than that found during the twelve hours of daylight (table 41). Finally table 44 shows that the amount of decrease is still less during the time when the species migrates in maximum numbers to the surface. In fact, the table shows an actual reversal in abundance and frequency relative to temperatures between 17°6-19°5 and 19°6-21°5. This reversal is probably due to the small number of hauls, but it is significant that the effect of high temperature on abundance and frequency of this species is less during twilight than during any other period of the day.

It was noted on page 121 that the number of specimens on the surface decreases abruptly after evening twilight vanishes. The above relations discovered between temperature and dis-

tribution leads me to suggest that the species migrates downward after twilight because, *the cause of upward migration being removed, it seeks deeper water where the temperature is lower.* Unfortunately this suppositon cannot be adequately tested because practically no closing net hauls were made with respect to temperature.

To summarize, it is demonstrated that, whether the data concern day, night, time of maximum abundance with respect to light, or time of minimum abundance, *S. bipunctata* is more abundant and frequent on the surface when the temperature is low than when it is high. It is further suggested that low surface temperatures *retard downward* and *aid upward* migrations, and that high surface temperatures *retard upward* and *aid downward* migrations.

VARIATION IN DISTRIBUTION OF *S. BIPUNCTATA* DUE TO SALINITY

From June 12, 1908, to April 21, 1910, 101 surface hauls were accompanied by water samples of which the salinities were computed. The salinity varied mainly from 33.549 to 33.693, although our data show a few instances outside these limits, the extremes being 33.381 and 34.069. Of the 101 hauls, 31 were scattered over the months of February, March, April, September, and November, while the remaining 70 were made during June and July. Now the salinities corresponding to the 31 hauls just mentioned average above 33.693. It is therefore advisable, owing to possible seasonal effects on distribution, to confine the following discussion to June and July data.

In attempting to correlate small changes in salinity with variations in the distribution of *S. bipunctata,* our data are not extensive enough to eliminate the effects of light and temperature. Consequently I have segregated the 70 June and July hauls into three groups according to whether the corresponding salinities were less than 33.605, between 33.605 and 33.648, or greater than 33.648. The surface distribution with respect to these groups is given in the following table.

TABLE 45

Surface Distribution of *S. bipunctata* with Respect to Salinity.

Salinity	Number of hauls		Number of hours	Number of specimens		Frequency	Average temperature
	Total	Successful		Total	Per hour		
33.604 or less	27	22	19.4	7243	373	81	17°.7
33.605–33.648	19	16	12.5	6941	555	84	19°.4
33.649 or more	24	16	21.0	7409	352	67	18°.8

These data indicate that, other things being equal, *S. bipunctata* accumulates on the surface in greater numbers when the salinity of the water is between 33.605 and 33.648. It may be objected that other things are not equal, that the average temperature corresponding to each salinity group differs, and that consequently the variations in abundance and frequency noted in the table are due to temperature and not to salinity. However, it has already been shown that the species is more abundant and frequent when the temperature is low. Therefore, if salinity has no effect, we should expect, as shown by temperature averages given in the table, the species to have been most abundant and frequent when the salinity was less than 33.605 and least abundant and frequent when it was between 33.605 and 33.648. This is obviously not the case. In fact the relations shown between temperature averages and salinity suggest that the effect of temperature is antagonistic to that of salinity. If this is true, then, by including only those hauls made when the temperature varied from 17°.6 to 19°.5 we should expect greater difference in abundance and frequency with respect to the three salinity groups than that found in the above data. The following table demonstrates that this is true.

TABLE 46

Effect of Salinity on Distribution of *S. bipunctata* when the Temperature varied from 17°.6 to 19°.5

Salinity.	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
33.604 or less	14	10	11.1	2430	219	71
33.605–33.648	9	8	8.2	6073	753	89
33.649 or more	18	13	16.1	6781	421	72

Comparing this with the preceding table, we see that the frequency and abundance corresponding to salinities less than

33.605 is much less in table 46 than in table 45. Now the average temperature corresponding to this salinity group is 17°7, which means that more hauls were made when the temperature was below 17°6 than when it was above 19°5. In fact during only two of the 27 hauls was the temperature above 19°5, while during 11 it was below 17°6. The effect of low temperatures, then, affords an explanation of why a reduction occurred in abundance from 373 to 219, and in frequency from 81 to 71.

Comparison of the two tables also shows that the frequency and abundance corresponding to salinities between 33.605 and 33.648 are much greater in table 46 than in table 45. As the temperature average corresponding to this salinity group is 19°4, we should infer that more hauls were made when the temperature was over 19°5 than when it was under 17°6. In fact the temperature during eight of the 19 hauls was above 19°5, while during only two hauls was it below 17°6. Hence, because high temperatures are detrimental to the accumulation of specimens on the surface, the reason is evident why the frequency increased from 84 to 89, and the abundance from 555 to 753.

Again, comparison of the two tables shows that the abundance and frequency corresponding to salinities greater than 33.648 increased respectively from 352 and 67 as given in table 45 to 421 and 72 as given in table 46. The temperature during four of the 24 hauls was more than 19°5, while during two hauls it was less than 17°6. This not only explains why the abundance and frequency increased, but also why the amount of increase is less than that corresponding to the second salinity group, and less than the amount of decrease corresponding to the first salinity group.

Finally, these tables demonstrate that salinity has a marked effect on the distribution of *S. bipunctata.* While the effect is evident in table 45, it is much greater when the antagonistic effects of variable temperatures are eliminated from the data, as in table 46. This means, then, that the species is most abundant and frequent on the surface when the salinity of the water varies between 33.605 and 33.648, that it is less when the salinity is

over 33.648, and still less when the salinity is below 33.605. It would be interesting to tabulate data concerning salinity with respect to temperatures varying from 15°9 to 17°5, and from 19°6 to 21°5, but the few hauls made under these conditions make this impossible.

In spite of the apparent significance of these data it may be argued that the hauls were distributed irregularly with respect to light. Consequently, if more night hauls were made when the salinity varied from 33.605 to 33.648 than when it was outside these limits, the greater abundance and frequency noted might be due to the effect of light and not to that of salinity. The following tables indicate that this is not so.

TABLE 47

Effect of Salinity on Distribution of *S. bipunctata* with respect to Night (6 p.m. to 6 a.m.)

Salinity	Number of hauls		Number of hours	Number of specimens		Frequency	Average temperature
	Total	Successful		Total	Per hour		
33.604 or less	15	12	10.3	6284	610	79	18°9
33.605–33.648	13	11	9.2	6763	735	85	19°6
33.649 or more	13	10	12.1	7264	600	77	19°1

TABLE 48

Including only hauls made when Temperature varied from 17°6 to 19°5

Salinity	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
33.604 or less	10	7	7.7	2329	302	70
33.605–33.648	7	6	6.95	5945	841	86
33.649 or more	11	9	10.6	6646	627	81

From these tables we see that, after day hauls are eliminated from consideration, *S. bipunctata* still persists in being more abundant and frequent on the surface when the salinity varies from 33.605 to 33.648. Furthermore, after the antagonistic effects of variable temperatures are eliminated by tabulating only those night hauls made when the temperature was between 17°6 and 19°5, table 48 shows *increased correlation* between abundance and frequency of the species and salinity of the water.

There is still a possibility that a maximum number of hauls corresponding to salinities between 33.605 and 33.648 were made

during twilight, and a maximum number corresponding to salinities outside these limits during darkness. Now of the ten hauls corresponding to salinities less than 33.605 and temperatures between 17°6 and 19°5, four were made during *evening twilight* (6 to 10 p.m.), and six during *morning twilight* (4 to 6 a.m.). Concerning salinities in the second group, all seven hauls were made during *evening twilight.* Finally of the eleven hauls corresponding to the third salinity group, four were made during *evening twilight,* four during *morning twilight,* and three during *darkness* (10 p.m. to 4 a.m.).

The distribution of hauls does show irregularity with respect to twilight, which may partly explain why the maximum abundance and frequency corresponds to the second salinity group. However, because of the three hauls made during *darkness,* which correspond to salinities more than 33.648, and the fact that the species maintains a *relative minimum* on the surface during darkness, we should expect both abundance and frequency to be less than that corresponding to salinities below 33.605. This is obviously not the case. It would seem, therefore, that while irregular distribution of hauls with respect to twilight has probably affected the relation between abundance and frequency of the species and salinity of the water, the data included in the above tables cannot be adequately explained without involving the effect of variations in salinity.

Finally, it is well to consider data based on daylight hauls. Such data are tabulated below.

TABLE 49

Effect of Salinity on Distribution of *S. bipunctata* with respect to Daylight (6 a.m. to 6 p.m.)

Salinity	Number of hauls		Number of hours	Number of specimens		Frequency	Average temperature
	Total	Successful		Total	Per hour		
33.604 or less	12	10	9.0	949	105	83	17°2
33.605–33.648	6	6	3.3	178	54	100	18°9
33.649 or more	11	5	8.9	145	16	22	18°9

The distribution with respect to salinity, as shown in this table, is not parallel with that shown in the preceding tables. However, since the temperature average corresponding to the

first salinity group is the *lowest,* it is certain that the abundance of 105 is too large for comparison with the 54 of the second, and the 16 of the third salinity group. Again, the hauls were unevenly distributed with respect to light. Corresponding to the first group, four hauls were made between 6 and 8 a.m., the time of *morning maximum abundance,* two between 4 and 6 p.m., and six between 8 a.m. and 4 p.m. Corresponding to the second group, five hauls were made between 8 a.m. and 4 p.m., one between 4 and 6 p.m., and *none between 6 and 8 a.m.* Concerning the third group, five hauls were made between 6 and 8 a.m., two between 4 and 6 p.m., and four between 8 a.m. and 4 p.m.

From these facts it follows that the hauls included in the above table were so distributed that both effect of light and temperature were antagonistic to that of salinity. Therefore, if the data were corrected with respect to these factors, the effect of variations in salinity ought to be more apparent. By including only data relative to hauls made between 8 a.m. and 4 p.m. the antagonistic effect of light may be mostly eliminated. The results of such elimination are shown in the following table.

TABLE 50

Effect of Salinity on the Surface Distribution of *S. bipunctata* based on Hauls between 8 a.m. and 4 p.m.

Salinity	Number of hauls		Number of hours	Number of specimens		Frequency	Average temperature
	Total	Successful		Total	Per hour		
33.604 or less	6	4	2.4	40	16	67	17°0
33.605–33.648	5	5	2.9	177	61	100	18°9
33.649 or more	4	2	3.6	30	8	50	19°05

Because only four of the entire fifteen hauls were made when the temperature of the water was between 17°6 and 19°5, it is impossible to standardize the data with respect to temperature. However, from the average temperatures recorded in the table, we can be sure that the abundance of 16 corresponding to the first salinity group is larger, and that of 8 corresponding to the third salinity group smaller than it would be if the effect of temperature could be eliminated. In spite of the antagonistic effects of temperature the table shows that, when disturbing light factors are eliminated, the maximum abundance and fre-

quency of the species is correlated with salinities between 33.605 and 33.648.

It is possible that the evidence in all the above data may be due merely to insufficient hauling. However, if this is true, it is difficult to see why the data *in every case indicate maximum abundance and frequency corresponding to salinities between 33.605 and 33.648.* This is true whether the data are tabulated with respect to temperature and light or not. Were such results due merely to chance or insufficient hauling we should expect such a variety of tabulation to introduce contradictions, but it does not. Consequently, it seems legitimate to conclude that, other things being equal, *S. bipunctata* is most abundant and frequent on the surface when the salinity of the water is between 33.605 and 33.648.

What this relation between salinity and distribution signifies is indeed puzzling. We know that salinity increases, somewhat irregularly, with the depth, and we also know that *S. bipunctata* is most abundant and frequent during the greater part of day and night in 15-20 fathoms. Are these facts correlated? Unfortunately June and July salinities corresponding to this depth have not been determined. We do know, however, that, while the average of the 70 surface salinities considered is 33.641, 31 were below 33.605, 14 between 33.605 and 33.648, and 25 above 33.648, which means that the salinity *most characteristic* of the surface is below 33.605. Now in 50 to 75 fathoms, while the average salinity is about 33.964, it is usually below 33.874. It is, therefore, obvious that between the surface and 50 fathoms a depth occurs in which the salinity is *normally* between 33.605 and 33.648. If this depth should prove to be 15-20 fathoms, the meaning of the above data would be much clearer. This speculation, however, proves nothing, but it does suggest a possible explanation of the correlation between salinity and distribution.

SEASONAL VARIATION IN THE DISTRIBUTION OF *S. BIPUNCTATA*

In discussing this question it is necessary to confine attention to surface hauls, for our closing nets were not employed sufficiently throughout the seasons to warrant adequate interpreta-

tions of the data obtained by them. Furthermore, the surface collecting with respect to season was so irregular and fragmentary that the meaning of the data is very obscure. Six hauls were made during each of the months of February, April, and September, 7 during November, 15 during March, 42 during July, and 53 during June. During August only one haul was made, and during January, May, October, and December none were made. In the following table the data for each month during which collections were made are given.

TABLE 51

Monthly Variation in Distribution of *S. bipunctata.*

Month	Number of hauls		Number of hours	Number of specimens		Frequency	Average temperature	Average Salinity	Distribution of hauls with respect to time of day					
	Total	Successful		Total	Per hour				4-6 a.m.	6-8 a.m.	8 a.m.-4 p.m.	4-6 p.m.	6-10 p.m.	10 p.m.-4 a.m.
February	6	6	7.25	718	93	100	13°.6	33.540	1	1	2	1	1	0
March	15	9	12.2	733	60	60	15.1	33.641	0	0	7	5	3	0
April	6	5	4.1	410	100	79	16.1	33.700	4	0	2	0	0	0
June	53	40	35.5	10672	301	75	17.9	33.608	4	5	19	8	17	0
July	42	26	30.3	10357	341	62	18.9	33.641	10	7	8	1	13	3
August	1	1	0.33	35	105	100	18.3	?	0	0	0	0	1	0
September	6	5	2.3	195	85	83	18.5	33.877	1	2	2	0	1	0
November	7	4	3.4	1444	424	57	17.9	33.848	0	1	4	2	0	0

It is evident from this table that the hauls were too unevenly distributed with respect to temperature, salinity, and especially time of day, to permit any significant comparison of the abundance and frequency of the species during the various months. Except for one November haul made between 8 and 10 a.m., which obtained 1240 specimens, the largest number obtained in any one haul during this month was 135. This indicates that the November abundance of 424 is too large to represent the usual abundance during this month. With this exception the months of June and July are apparently those of maximum abundance, although this appearance may be entirely due to the greater number of twilight hauls made during these months. Until more collecting is accomplished with respect to season it will be impossible to determine its effect on the distribution of this species.

EFFECT OF LOCALITY ON THE DISTRIBUTION OF *S. BIPUNCTATA*

As in the case of seasonal collecting, our closing nets were not employed at all stations. Consequently a consideration of the effect of locality, or distance from the coast, on distribution limits us to surface collections. While definite seasonal effects on distribution could not be discovered, it is very probable that some such effect exists. It seems, therefore, advisable to restrict this consideration to June and July data. These data are summarized in the accompanying table.

From this table we find that conditions of salinity, temperature, and time of day under which the hauls were made varied from station to station. With such an amount of variation no significant effect of locality on distribution can be detected. From the table we see that those stations where the abundance of specimens is greatest are those where the most twilight hauls were made. This indicates that very little, if any, difference in distribution exists with respect to distance from the coast. At any rate, until more definite collecting regarding this problem is accomplished, no definite conclusions are possible.

TABLE 52

Surface Distribution of *S. bipunctata* with Respect to Locality.

Station	Latitude	Longitude	Number of hauls		Number of hours	Number of Specimens		Distribution of hauls with respect to time						Average temperature	Average Salinity	Distance from coast.
			Total	Successful		Total	Per hour	4-6 a.m.	6-8 a.m.	8 a.m. to 4 p.m.	4-6 p.m.	6-10 p.m.	10 p.m. to 4 a.m.			
1	32°(30′–40′)	117°(20′–30′)	2	1	0.9	16	19	0	0	2	0	0	0	20°0	33.617	Bet. 10 & 20 miles from coast.
2	(30′–40′)	(30′–40′)	1	0	0.3	0	0	0	0	1	0	0	0	18.9	(?)	Bet. 20 & 30 miles from coast.
3	(40′–50′)	(20′–30′)	3	1	1.8	5	3	0	0	3	0	0	0	21.0	33.699	Bet. 10 & 20 miles from coast.
4	(40′–50′)	(30′–40′)	4	1	2.3	25	11	0	0	3	1	0	0	18.4	33.601	Bet. 20 & 30 miles from coast.
5	(40′–50′)	(40′–50′)	1	1	0.7	20	30	0	0	1	0	0	0	17.1	33.630	Bet. 30 & 40 miles from coast.
6	(40′–50′)	(50′–60′)	2	1	1.55	75	48	0	0	1	0	1	0	18.5	33.580	Bet. 40 & 50 miles from coast.
7	(40′–50′)	118°(20′-30′)	3	2	1.7	659	387	1	1	1	0	0	0	19.2	33.652	Bet. 5 & 10 miles from San Clemente.
8	(50′–60′)	117°(10′–20′)	7	4	7.6	782	103	2	0	1	0	3	1	18.8	33.733	Bet. 0 & 5 miles from La Jolla.
9	(50′–60′)	(20′–30′)	29	19	19.2	7090	368	7	4	5	0	11	2	19.3	33.657	Bet. 10 & 20 miles from coast.
10	(50′–60′)	(30′–40′)	30	25	22.3	14662	657	4	3	4	4	14	0	17.8	33.594	Bet. 20 & 30 miles from coast.
11	(50′–60′)	(40′–50′)	2	2	1.25	70	56	0	0	2	0	0	0	16.5	(?)	Bet. 30 & 40 miles from coast.
12	(50′–60′)	118°(0′–10′)	1	1	0.4	1	2	0	0	0	1	0	0	19.1	33.630	Bet. 50 & 60 miles from coast.
13	(50′–60′)	(10′–20′)	1	0	0.3	0	0	0	0	1	0	0	0	17.5	(?)	Bet. 10 & 20 miles from San Clemente.
14	(50′–60′)	(20′–30′)	2	1	1.3	9	7	0	0	2	0	0	0	18.5	33.690	Bet. 5 & 10 miles from San Clemente.
15	33°(0′–10′)	117°(30′–40′)	1	1	0.2	1	5	0	0	1	0	0	0	16.5	33.432	Bet. 10 & 20 miles from coast.
16	(0′–10′)	(40′–50′)	1	1	0.5	25	50	0	0	1	0	0	0	16.5	(?)	Bet. 20 & 30 miles from coast.
17	(10′–20′)	118°(0′–10′)	1	0	0.3	0	0	0	0	1	0	0	0	(?)	(?)	Bet. 10 & 20 miles from Catalina.
18	(20′–30′)	(10′–20′)	1	0	0.3	0	0	0	0	1	0	0	0	(?)	(?)	Bet. 5 & 10 miles from Catalina.
19	32°(20′–30′)	(10′–20′)	1	1	0.4	3	7	0	1	0	0	0	0	18.9	(?)	Bet. San Clemente and Cortez banks.
20	(20′–30′)	119°(0′–10′)	2	2	0.8	2527	3032	0	2	0	0	0	0	16.5	33.457	On Cortez banks.

SIGNIFICANCE OF THE DATA CONCERNING THE DISTRIBUTION OF *S. BIPUNCTATA.*

In the foregoing pages it is demonstrated that *S. bipunctata* is most abundant on the surface during twilight when the temperature of the water is between 15°.9 and 17°.5, and the salinity between 33.605 and 33.648. Furthermore, we found the species confined to the upper 150 fathoms of water, and mainly above 75 fathoms. Our data also indicate that during darkness and intense light the species is most abundant and frequent in 15-20 fathoms, migrating to the surface only during the hours of twilight. In other words, the region of 15-20 fathoms is probably the center from which the species migrates. Now what do these facts taken together signify?

Let us assume that the *usual* conditions of light, temperature, and salinity occurring in 15-20 fathoms are those which determine the migrations of this species. On this assumption, if the intensity of the light in this depth during the day approximates twilight, the migration of the species toward the surface is readily explained. Again, if the temperature in 15-20 fathoms is *normally* between 15°.9 and 17°.5, or less than 15°.9, and the salinity between 33.605 and 33.648, the tendency of the species to remain on the surface in greater numbers when these conditions are realized is also readily explained.

What, then, are the usual conditions of light, temperature, and salinity occurring in 15-20 fathoms? Concerning light, we know its intensity below the surface rapidly decreases as the depth increases, and it is generally agreed that it is very subdued below 100 or 200 fathoms. Now, since the species begins to accumulate on the surface at sundown and sunrise, it is certain that the *earlier* or *brighter* evening twilight and the *later* or *brighter* morning twilight initiates the upward migrations. This fact, together with the time of day in which we found the maximum number of specimens in the various depths, indicates that during the greater part of the day *bright twilight* conditions normally occur in 15-20 fathoms. Again, with respect to temperature, while observations were not taken in connection with closing net hauls, our records show that the usual June and July temperature in 15-20 fathoms is approximately 15°-16°. Finally,

while salinity determinations for 15-20 fathoms were not made, sity it is possible, as pointed out on page 139, that the salinity is usually between 33.605 and 33.648.

Our data, then, seem to justify the truth of the above assumption. To prove it, however, would require carefully planned collecting with all conditions of light-intensity in each depth recorded, as by an automatic light meter, systematic closing net hauls with corresponding temperature observations in each depth, and salinity determinations corresponding to each haul in each depth.

Notwithstanding that these more accurate methods of collecting were not employed, from what data we have the following conclusions may be drawn:

1. The region of 15-20 fathoms is the center from which the species migrates or, in other words, it is the depth in which the greatest number of optimum conditions favorable to this species are found.

2. It migrates to the surface at sundown and sunrise because the conditions of light intensity at these times are *similar* to those occurring in 15-20 fathoms during the greater part of the morning and afternoon.

3. Other things equal, it remains on the surface in greater numbers when the temperature of the water is between 15°.9 and 17°.5, because this is approximately the normal temperature occurring in 15-20 fathoms.

4. It remains on the surface in greater numbers when the salinity of the water is between 33.605 and 33.648 because this approximates the normal salinity in 15-20 fathoms. This, at present, is *barely suggested* by our data; it still remains to be proven.

5. The animals leave the surface at night because the light incentive which caused them to migrate upward is absent, and they presumably return to the region of 15-20 fathoms where optimum temperature and other conditions occur.

6. Probably light has more pronounced effect on vertical distribution than temperature or salinity because its variations are more regular and periodic.

7. All individuals do not react toward light, temperature, and salinity in the same way. While the majority migrate toward the surface during twilight hours, and toward deeper water during intense light and darkness, *a few almost always remain in deeper water during twilight, and on the surface during intense light and darkness.* Similar individual differences occur with respect to temperature and salinity. This means that those optimum conditions favorable to the species as a whole are not favorable to each individual or, in other words, the characteristic organization, constitution, or physiological state of each individual modifies the effect of light, temperature, and salinity on its behavior.

DISTRIBUTION OF *S. SERRATODENTATA.*

Of the 6,499 specimens of this species obtained, 76 were taken from the surface, 676 in open vertical nets from depths varying from 500 to 25 fathoms, 5,299 in vertical closing nets from between 300 and 10 fathoms, and 448 in horizontal closing nets. The 76 obtained from the surface were distributed in 14 or 9.5 per cent of the 148 hauls made. Of 68 vertical closing net hauls 46 or 68 per cent obtained some specimens, while of the 118 horizontal closing net hauls 33 or 18 per cent were successful, and of 41 open vertical net hauls 14 or 34 per cent obtained the species. More complete data concerning the surface and closing net hauls are given in the following tables.

TABLE 53

Vertical Distribution of *S. serratodentata* based on Surface and Horizontal Closing Net Hauls.

Depth in fathoms	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
0	136	12	96.7	74	1	9
4–6	11	0	3.3	0	0	0
7–12	15	1	4.6	15	3	7
15–20	13	1	3.5	4	1	8
25–35	19	5	5.3	15	3	26
40–75	20	5	5.7	91	16	25
100–150	19	9	6.5	106	17	47
160–220	10	9	3.1	174	56	90
250–350	11	5	5.4	43	8	27

TABLE 54

Vertical Distribution of *S. serratodentata* based on Vertical Closing Net Hauls.

Depth in fathoms	Number of hauls		Distance of haul in fathoms	Number of specimens		Frequency
	Total	Successful		Total	Per 50 fathom haul	
0–10	11	0	10	0	0	0
10–25	5	2	15	33	22	40
25–50	10	5	25	27	5	50
50–75	9	7	25	190	44	78
75–100	9	4	25	442	98	45
100–150	10	8	50	773	77	80
150–200	9	9	50	1351	150	100
200–250	8	7	50	1439	179	88
250-300	5	4	50	1057	211	80

It is significant that the data in both tables agree that this species is mainly mesoplanktonic, and that the depth of maximum abundance and frequency is below 150 fathoms. They disagree in detail but, owing to very different methods of collecting, and of different depths considered, this is to be expected. From the fact that the frequency and abundance are more nearly parallel in the former than in the latter table, the data in the former are probably more reliable.

In arranging the above data with respect to day and night, the following table suggests that the species migrates upward during the night.

TABLE 55

Day and Night Distribution of *S. serratodentata* based on Surface and Horizontal Closing Net Hauls.

Daylight or 6 a.m. to 6 p.m.

Depth in fathoms	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
0	78	6	54.4	48	1	8
4–6	5	0	1.8	0	0	0
7–12	8	0	2.4	0	0	0
15–20	7	0	1.9	0	0	0

TABLE 55—*Continued*

Daylight or 6 a.m. to 6 p.m.

Depth in fathoms	Number of hauls		Number of hours	Number of specimens		Frequency
	Total	Successful		Total	Per hour	
25–35	12	2	3.3	3	1	16
40–75	12	2	3.2	82	28	16
100–150	8	4	2.5	59	26	50
160–220	6	5	1.8	132	73	83
250–350	9	2	5.1	26	5	22
Night or 6 p.m. to 6 a.m.						
0	58	6	42.3	30	1	10
4–6	6	0	1.5	0	0	0
7–12	7	1	2.2	15	7	14
15–20	6	1	1.6	4	2	16
25–35	7	3	2.0	21	10	43
40–75	8	2	2.6	9	3	25
100–150	11	5	4.1	47	11	45
160–220	4	4	1.3	42	32	100
250–350	2	1	0.3	17	57	50

This table shows clearly that the species was practically never obtained during daylight above 40 fathoms, while during the night it occurred above this depth. While the difference between day and night distribution is not so striking as in the case of *S. bipunctata,* the data point in exactly the opposite direction to those of Fowler (1905). In the Biscayan plankton he found *S. serratodentata* more frequent on the surface during daylight. He has, however, regarded the day as including twilight, while I have regarded the night as including it. This, together with the fact that in table 55 we find very little distinction between day and night surface distribution, and that the number of specimens is so small, may explain the difference noted.

In connection with day and night distribution it is significant to discover that, when data obtained with vertical closing nets are segregated as in table 56, similar variation is found.

TABLE 56

Day and Night Distribution of *S. serratodentata* based on Vertical Closing Net Hauls.

Depth in fathoms	Number of hauls		Distance of haul in fathoms	Number of specimens		Frequency
	Total	Successful		Total	Per 50 fathom haul	
Daylight or 6 a.m. to 6 p.m.						
0–10	7	0	10	0	0	0
10–25	3	1	15	13	14	33
25–50	6	2	25	5	1	33
50–75	6	4	25	103	34	66
75–100	6	3	25	314	105	50
100–150	6	5	50	561	93	83
150–200	6	6	50	1310	218	100
200–250	7	7	50	1439	205	100
250–300	3	3	50	1056	352	100
Night or 6 p.m. to 6 a.m.						
0–10	4	0	10	0	0	0
10–25	2	1	15	20	33	50
25–50	4	3	25	22	11	75
50–75	3	3	25	87	58	100
75–100	3	1	25	128	86	33
100–150	4	3	50	212	53	75
150–200	3	3	50	41	14	100
200–250	1	0	50	0	0	0
250–300	2	1	50	1	1	50

While these data are not strictly comparable to those obtained with horizontal nets, they show clearly that during daylight the species is less numerous above 75 fathoms than it is during the night.

In the data concerning vertical closing net hauls one instance is found where two similar series of hauls were made with the same net on the same day at approximately the same location. One series was made between 1:10 and 3:24 p.m. and the other between 4:20 and 7:34 p.m. It will be interesting, therefore, to compare the *actual* number of animals obtained from each depth during the afternoon and evening series. Such data are given in the following table.

TABLE 57

Two Series of Hauls containing *S. serratodentata* made with the Nansen Closing Net on March 17, 1910, at 32° 50.0 N and 117° 30.0 W.

Hauls made between 1:10 and 3:24 P.M.					Hauls made between 4:20 and 7:34 P.M.				
			Number of specim'ns					Number of specim'ns	
Haul number	Time	Depth	Total	Per 50 fathoms	Haul number	Time	Depth	Total	Per 50 fathoms
2077	3:24 p.m.	25–10	0	0	2104	7:34 p.m.	25–10	20	66
2076	3:14 p.m.	50–25	4	8	2100	7:24 p.m.	50–25	12	24
2075	2:59 p.m.	75–50	12	24	2099	6:53 p.m.	75–50	78	156
2074	2:37 p.m.	100–75	263	526	2095	6:37 p.m.	100–75	128	256
2073	2:23 p.m.	150–100	156	156	2094	6:17 p.m.	150–100	165	165
2069	2:02 p.m.	200–150	400	400	2090	5:58 p.m.	200–150	100	100
2068	1:57 p.m.	250–200	715	715	2089	5:37 p.m.	250–200	129	129
2067	1:10 p.m.	300–250	478	478	2081	4:20 p.m.	300–250	316	316

This table shows that the species was most abundant above 75 fathoms during late afternoon and early evening, while below this depth it was most abundant during early afternoon. It is significant that this result is very similar to that derived from consideration of the average number of specimens obtained by both horizontal and vertical nets. It is quite certain, therefore, that the species migrates toward the surface when light is subdued. Owing to the small number of animals obtained it is impossible to determine accurately its center of migration, but the data suggest that this center is between 100 and 200 fathoms.

All our data show that the species was rarely found above 10 fathoms, which suggests the question: Why did it occur on the surface? Of the fourteen hauls in which it appeared, six were made between 6 and 10 p.m., one between 10 a.m. and noon, three between 8 and 10 a.m., and four between 6 and 8 a.m. It seems, therefore, that their occurrence on the surface was not correlated with intensity of light, or time of day. Again, fifty-four specimens were obtained when the temperature of the water was between 15°.5 and 17°.8, eight when it was between 18°.6 and 19°.3, and fourteen when it was between 20°.5 and 22°.2. This possibly means that low temperatures caused them to remain in greater numbers on the surface, but it can not explain what brought them there. Finally, the salinities corresponding to the fourteen hauls varied from 33.563 to 34.069 so that it seems impossible that this was a factor. Their occurrence on the surface was undoubtedly due to some unusual surface conditions. Low temperature was possibly one, but what the others were is not apparent in our data.

Considering all the data, the following conclusions may be drawn:

1. *S. serratodentata* occurs mainly in the mesoplankton.

2. It is maximum in abundance and frequency in the region of 200 fathoms.

3. It is rarely taken above 40 fathoms during daylight, but occurs above this depth at night.

4. The species probably migrates toward the surface when twilight is very subdued, but rarely ascends above 10 fathoms.

5. Its center of migration, or the depth in which the greatest number of optimum conditions are found, is probably between 100 and 200 fathoms.

6. Its exceptional occurrence on the surface is probably correlated with some unusual surface conditions, of which low temperature may be one.

DISTRIBUTION OF *S. LYRA*

Of the 272 specimens of this species only four were obtained from the surface. Open vertical nets obtained 61 from a variety of depths below 75 fathoms, horizontal closing nets obtained 112 from below 25 fathoms, and vertical closing nets obtained 94 from below 50 fathoms. All these data agree that the species occurs very rarely near the surface. The exact way in which the number of specimens obtained with surface and horizontal closing nets were distributed with respect to depth is given in the following table:

TABLE 58

Vertical Distribution of *S. lyra* based on Surface and Horizontal Closing Net Hauls.

Depth	Number of hauls		Number of hours	Number of specimens			Frequency
	Total	Successful		Total	Per hour	Per 10 hrs.	
0	136	2	96.7	4	1—	1—	1.4
4–6	11	1	3.3	1	1—	3	9.0
7–12	15	0	4.6	0	0	0	0
15–20	13	0	3.5	0	0	0	0
25–35	19	4	5.3	11	2+	21	21
40–75	20	2	5.7	9	2—	15	10
100–150	20	6	6.5	20	3+	31	30
160–220	10	4	3.1	17	6—	57	40
250–350	11	3	5.4	54	10	100	27

The per 10 hour column is supplied in order to eliminate the fractions which occur when the number of specimens is expressed according to one hour hauls.

This table shows clearly that the species rarely occurs above 25 fathoms, and that it increases in abundance and frequency at least down to 250 fathoms. In 25-35 fathoms, however, there is an irregularity in the increase and it is interesting to notice that when the night hauls are eliminated this irregularity disappears This is shown in table 59.

TABLE 59

Daylight Distribution of *S. lyra* (6 a.m. to 6 p.m.) based on Surface and Horizontal Closing Net Hauls.

Depth	Number of hauls		Number of hours	Number of specimens			Frequency
	Total	Successful		Total	Per hour	Per 10 hrs.	
0	78	2	54.4	4	1—	1—	2.5
4–6	5	0	1.8	0	0	0	0
7–12	8	0	2.4	0	0	0	0
15–20	7	0	1.9	0	0	0	0
25–35	12	2	3.3	2	1—	9	17
40–75	12	1	3.2	8	2+	25	8
100–150	8	2	2.5	12	5—	48	25
160–220	6	3	1.8	16	8+	88	50
250–350	9	2	5.1	52	10+	102	22

TABLE 60

Night Distribution of *S. lyra* (6 p.m. to 6 a.m.) based on Surface and Horizontal Closing Net Hauls.

Depth	Number of hauls		Number of hours	Number of specimens			Frequency
	Total	Successful		Total	Per hour	Per 10 hrs.	
0	58	0	42.3	0	0	0	0
4–6	6	1	1.5	1	1—	7	17
7–12	7	0	2.2	0	0	0	0
15–20	6	0	1.6	0	0	0	0
25–35	7	2	2.0	9	4+	45	29
40–75	8	1	2.6	1	1—	4	13
100–150	11	4	4.1	8	2—	19	36
160–220	4	1	1.3	1	1—	8	25
250–350	2	1	0.3	2	6+	66	50

Table 59 shows that during daylight the species occurs rarely above 40-75 fathoms, and that it increases regularly in abundance from nine in 25-35 fathoms to 102 in 250-350 fathoms. The increase in frequency is more irregular, but this is to be expected because so few successful hauls were made. When compared with the night distribution, as shown in table 60, the

species is found less abundant above and more abundant below 40 fathoms during the day. While the data do not prove nocturnal migration toward the surface they indicate that such migration occurs.

Of the 94 specimens obtained with vertical closing nets one was taken from between 50 and 75 fathoms, five between 75 and 100 fathoms, seven between 100 and 150 fathoms, 33 between 150 and 200 fathoms, 26 between 200 and 250 fathoms, and 22 between 250 and 300 fathoms. Expressing these numbers according to unit distance of haul they are 2, 11, 7, 36, 33, and 55. (In this instance, in order to avoid fractions of animals, 500 instead of 50 fathoms is considered as the unit distance of haul.) The frequencies corresponding to these numbers are 11, 33, 30, 66, 75, and 60. This means that the species did not occur above 50 fathoms, and that it increased in abundance from two in 50-75 fathoms, to 55 in 250 to 300 fathoms, and in frequency from 11 in 50-75 fathoms to 75 in 200-250 fathoms.

When vertical closing net hauls are segregated with respect to day and night, it appears that only one specimen was obtained at night. Now we learn from table 56 that the number of night hauls in each depth was very small. This together with the fact that the total number of specimens was only 94, will possibly explain why the animals were not obtained at night. However, whatever the reason may be, it seems certain, from data concerning horizontal closing net hauls, that the absence of the species was not due to light.

Hence, when all the data are considered, we find that, while the species does not occur abundantly in the San Diego region, the following conclusions are suggested:

1. The species is typically mesoplanktonic.

2. It occurs very rarely above 25 fathoms and is most abundant and frequent between 200 and 300 fathoms.

3. It occurs in greater numbers within 35 fathoms of the surface during the night than during the day.

4. It is very possible that nocturnal migrations toward the surface occur, although their meaning is obscure.

5. Its center of migration is probably below 200 fathoms.

DISTRIBUTION OF OTHER SPECIES

Distribution of S. hexaptera

Of 28 specimens obtained, 11 were taken from the surface, five with horizontal closing nets, three with vertical closing nets, and nine with open vertical nets. All our data concerning the distribution of these specimens are given in the following table.

TABLE 61

Data concerning the Distribution of *S. hexaptera.*

Haul number	Date	Time of Day	Depth	Number of specimens: Total	Number of specimens: Number per 10 hrs. hauling
	Horizontal Net Hauls.				
	1904				
275	Sept. 17	7:30 a.m.	0	2	
	1905				
412	Feb. 25	6:00 a.m.	0	4	
	1908				1+
1417	June 19	10:20 a.m.	0	2	
1535	July 8	7:30 a.m.	0	2	
	1909				
1686	June 22	4:00 a.m.	0	1	
	1908				
1476	June 2	11:00 a.m.	50	1	10—
	1909				
1929	Sept. 3	2:53 p.m.	50	4	
	Vertical Closing Net Hauls				
	1910				
2038	Mar. 15	3:52 p.m.	75–50	2	
2094	Mar. 17	6:17 p.m.	150–100	1	
	Open Vertical Net Hauls.				
	1905				
468	Apr. 22	6:00 a.m.	45	1	
462	Apr. 15	6:00 a.m.	110	4	
	1908				
1492	June 25	10:10 a.m.	210	1	
1516	June 30	9:20 a.m.	250	2	
1527	July 2	11:20 a.m.	500	1	

From these data we see that this species is irregularly distributed. So few specimens were obtained that it is difficult to tell whether it typically occurs in the mesoplankton or not. However, excepting at the surface it has not been obtained above 45 fathoms, and even those from the surface when expressed in terms of number per 10 hours of hauling become insignificant

beside those taken in 50 fathoms. It is probable, therefore, that the species occurs mainly in the mesoplankton or lower epiplankton.

Distribution of S. planktonis

Of the 36 specimens obtained, two were taken from the surface, six with horizontal closing nets, 15 with vertical closing nets, and 13 with open vertical nets. All data concerning this species are given in the following table.

TABLE 62

Data concerning the Distribution of *S. planktonis.*

Haul number	Date	Time of Day	Depth	Number of specimens: Total	Number of specimens: Number per 100 hour-haul
	Horizontal Net Hauls.				
	1907				
1422	Nov. 2	5:00 p.m.	0	1	1+
	1908				
1560	July 18	7:20 a.m.	0	1	
1476	June 21	11:00 a.m.	50	1	18+
1927	Sept. 3	1:22 p.m.	125	1	15+
1926	Sept. 3	12:21 p.m.	200	1	32+
1550	July 16	11:45 a.m.	350	3	56—
	Vertical Closing Net Hauls				Per 500 fathom haul
	1910				
2112	Apr. 19	9:55 a.m.	200–150	1	1+
2001	Feb. 17	10:06 a.m.	250–200	2	7+
2031	Mar. 15	2:01 p.m.	250–200	3	
2052	Mar. 16	2:41 p.m.	250–200	1	
2067	Mar. 17	1:10 p.m.	300–250	2	16
2081	Mar. 17	4:20 p.m.	300–250	6	
	Open Vertical Net Hauls				
	1904				
236	Aug. 9	7:10 a.m.	2	1	
	1908				
1508	June 27	5:58 a.m.	150	2	
1492	June 25	10:10 a.m.	210	3	
	1910				
2088	Mar. 17	5:11 p.m.	250	3	
	1908				
1468	June 19	9:35 a.m.	290	2	
1527	July 2	11:20 a.m.	500	2	

These data indicate that this species occurs mainly below 100 fathoms, although at times it is found on the surface. We may

only conclude, therefore, that the species is typically mesoplanktonic and that it is apparently most abundant in the region of 300 fathoms.

Distribution of S. enflata

This species was obtained in only four surface hauls, which yielded a total of 6607 specimens. Of this number 6600 were obtained in two hauls (411 and 412) made on February 25, 1905. Six of the remaining seven were obtained on April 26, 1905, and the other specimen on June 11, 1908. In addition to the surface hauls, the open vertical net obtained 3520, but both horizontal and vertical closing nets failed to obtain a single specimen. This may be due to the fact that no specimens were obtained since June 19, 1908, before which date very few closing net hauls were made. All data regarding the species are contained in the following table.

TABLE 63

Data concerning the Distribution of *S. enflata.*

Haul	Date	Time of day	Depth	Temperature	Number of specimens
	1905				
411	Feb. 25	6:00 a.m.(?)	0	15°.5	3500
412	Feb. 25	6:00 a.m.(?)	0	15°.5	3100
473	Apr. 29	6:00 a.m.(?)	0	16°.5	6
	1908				
1416	June 11	2:25 p.m.	0	?	1
		Open Vertical Net Hauls.			
	1904				
234	Aug. 8	9:30 a.m.	5	?	1
235	Aug. 8	10:00 a.m.	10	?	5
251	Aug. 27	7:10 a.m.	10	?	1
274	Sept. 17	7:00 a.m.	10	?	3500
	1905				
468	Apr. 22	6:00 a.m.	45	?	10
	1907				
1398	July 3	10:00 a.m.	75	?	1
	1905				
462	Apr. 15	6:00 a.m.	110	?	1
	1908				
1468	June 19	9:35 a.m.	290	?	1

From these data we may be sure that this species is strictly epiplanktonic. It can not be regarded as typical of the San Diego region, and since it occurs elsewhere on the surface when the temperature of the water is as high as 34°, it seems probable that it was carried into this region by currents from the more tropical seas. We have, however, found it to occur in midwinter when the temperature of the water was as low as 15°.5, which, on the above supposition, makes its distribution decidedly puzzling.

Distribution of S. neglecta

This species, like *S. enflata,* can scarcely be considered typical of this region. It seems to be confined strictly to the surface, for it was not obtained in either open vertical nets or horizontal or vertical closing nets. Furthermore, of 127 specimens obtained, all but five were taken in three hauls made during February and April, 1905. Like *S. enflata,* the species is typical of the epiplankton of tropical seas, and its occurrence in the region of San Diego during the winter when the temperature of the water was 15°.5 is likewise puzzling. Were it not for the low temperature noted, I should believe the species was carried here by currents from the tropics. It is possible, of course, that this species, as well as *S. enflata,* normally occurs here during the winter months and that it was not obtained in greater numbers because practically no winter collections were made. This, however, seems hardly probable. Our data warrant but one conclusion, namely: *S. neglecta,* when it occurs at all in this region, is confined to the upper epiplankton.

Distribution of Spadella draco

But one specimen was obtained, and that one in surface haul 411. Like *S. enflata* and *S. neglecta,* this species occurs typically in the warmer water of the more tropical seas, and the reason why it occurred in this region remains obscure.

Distribution of Eukrohnia hamata

Of 61 specimens obtained, six were taken in horizontal closing nets below 100 fathoms, 16 in vertical closing nets below 25

fathoms, and 39 in open vertical nets below 250 fathoms. None were found on the surface. These data agree that this species is typically mesoplanktonic, that it occurs occasionally above 100 fathoms, but not above 25 fathoms. Owing to the small number of specimens obtained any further conclusions are impossible.

Distribution of E. subtilis

Of 50 specimens obtained, two were taken with horizontal closing nets from 160 fathoms, and four from 200 fathoms. The vertical closing nets obtained nine from between 75 and 50 fathoms, two between 200 and 150 fathoms, 25 between 250 and 200 fathoms, and five between 300 and 250 fathoms. Finally, the open vertical net obtained three in a haul from 250 fathoms to the surface. From these data it is apparent that this species occurs in greatest number between 200 and 250 fathoms. It has never been taken above 50 and rarely above 150 fathoms. We can be sure, therefore, that this species is mesoplanktonic and that its probable center of migration is between 200 and 250 fathoms.

GENERAL SUMMARY AND CONCLUSIONS.

We have taken ten species of Chaetognatha from the vicinity of San Diego, none of which are new. They are *Sagitta bipunctata, S. serratodentata, S. lyra, S. hexaptera, S. planktonis, S. enflata, S. neglecta, Spadella draco, Eukrohnia hamata,* and *E. subtilis.* Of these only *S. bipunctata* was obtained in large enough numbers and frequently enough to permit extensive analysis of its manner of distribution. Concerning it we found:

1. It is typically epiplanktonic, occurring between the surface and 150 fathoms.

2. It is rarely found below 75 fathoms, and it is most frequent and abundant between the surface and 20 fathoms.

3. Between 6 p.m. and 6 a.m. the species is most abundant above 15 fathoms, while between 6 a.m. and 6 p.m. it is most abundant below 15 fathoms.

4. The species appears in maximum abundance on the surface and in 4-6 fathoms between 6 and 8 p.m., in 7-12 fathoms between

4 and 6 a.m., in 15-20 fathoms between 8 and 10 a.m., in 25-35 fathoms between noon and 2 p.m., and in 40-75 fathoms between 10 a.m. and noon.

5. In all depths above 25 fathoms the species attains maximum abundance twice during the day, one maximum occurring between 6 and 10 a.m., and the other between 6 and 8 p.m. Below 25 fathoms only one maximum occurs in each depth, and that one between 10 a.m. and 2 p.m.

6. The species attains its morning maximum on the surface within an hour after sunrise and its evening maximum within an hour after sunset.

7. Other conditions constant, the species is most frequent and abundant on the surface when the temperature of the water is between 15°.9 and17°.5.

8. It also tends to remain on the surface in greater numbers when the salinity is between 33.605 and 33.648.

9. No significant correlation between season and variations in distribution could be detected.

10. No significant correlation between locality, or distance from the coast, and variations in distribution were found.

From these facts we concluded:

1. It is probable that the region of 15-20 fathoms is the center from which the species migrates or, in other words, it is the depth where the greatest number of optimum conditions favorable to the species are found.

2. It migrates to that depth in which the intensity of light is similar to that occurring throughout a large part of the day in 15-20 fathoms, and it remains in greater numbers in that depth when the temperature and salinity of the water, and probably other unknown conditions, are similar to those typical of 15-20 fathoms.

3. This explains why the species occurs in maximum number on the surface during morning and evening twilight, why the evening maximum is the largest, why it leaves the surface so quickly after it becomes dark, why it is more abundant on the

surface when the temperature is below 17°5, and possibly why it is more abundant when the salinity is between 33.605 and 33.648.

Concerning *S. serratodentata* we found:

1. It is typically mesoplanktonic, being most abundant and frequent in the region of 200 fathoms.

2. It is rarely taken above 40 fathoms and practically never above 10 fathoms, and is obtained from these depths only at night.

3. It is probable that the species migrates toward the surface when twilight is very subdued.

4. Its exceptional occurrence on the surface is undoubtedly correlated with some unusual surface conditions, of which low temperature may be one.

5. Its center of migration, or the depth in which the greatest number of optimum conditions are found, is probably between 100 and 200 fathoms.

Concerning *S. lyra* we found:

1. It is typically mesoplanktonic, rarely occurring above 25 fathoms, and irregularly increasing in abundance and frequency at least to 250 fathoms.

2. It occurs in greater numbers within 35 fathoms of the surface during the night than during the day, which indicates that nocturnal migrations toward the surface probably occur.

3. Its center of migration is probably below 200 fathoms.

Concerning the remaining species we found:

1. *S. planktonis* is entirely confined to the mesoplankton because it was not obtained above 100 fathoms. Its center of migration is probably in the region of 300 fathoms.

2. *S. hexaptera* probably belongs in the mesoplankton or lower epiplankton, although it occurs to a certain extent in 75, 50, and 45 fathoms, and on the surface.

3. *Sagitta enflata*, *S. neglecta*, and *Spadella draco* cannot be regarded as typical of the San Diego region. They were all taken from above 10 fathoms, and are, therefore, strictly epiplanktonic.

4. *Eukrohnia hamata* is typically mesoplanktonic. It has, however, been taken above 100 but not above 25 fathoms.

5. *E. subtilis* was not taken above 50 and only rarely above 150 fathoms. The species is, therefore, mesoplanktonic and its center of migration is probably between 200 and 250 fathoms.

6. Comparison of the distribution of all the species shows conclusively that manner of distribution is correlated with the organization of the species. In other words, the distinctive manner in which each species is distributed is as much a *specific character* as is its structure.

Such evidence as was obtained, especially concerning *S. bipunctata*, can not be regarded as *proving* the conclusions advanced in this paper. To prove would require much more collecting with respect to light, temperature, salinity, gas content, season, location, and other factors. It would further require special apparatus for determining the amount of light throughout day and night in the various depths, and the number, direction, velocity, and alterations of currents in all depths. It would also require determination of net coefficients, or better, the use of nets of similar size, mesh, and filtering capacities in collecting in all depths. To call attention to this necessity for improved and more complete methods in collecting is one of the greatest values of this paper. However, in spite of the less adequate methods employed, the data strongly support the conclusions made.

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EXPLANATION OF PLATES

Figures on plates 1 and 2 are intended primarily to represent specific differences in transparency and general appearance. Drawings were made on Ross stipple board, nos. 5 and 8, black.

All figures drawn with the camera lucida.

PLATE 1

Fig. 1. *Sagitta enflata* Grassi. × 3.

Fig. 2. *Sagitta hexaptera* d'Orbigny. × 3.

Fig. 3. *Sagitta lyra* Krohn. × 3.

Fig. 4. *Sagitta serratodentata* Krohn. × 3.

Fig. 5. *Sagitta bipunctata* Quoy et Gaimard. × 3.

Fig. 6. *Sagitta planktonis* Steinhaus. × 3.

ABBREVIATIONS

col.—collarette.
int.—intestine.
ov.—ovary.
seiz. j.—seizing jaws.
sem. v.—seminal vesicle.
vent. g.—ventral ganglion.

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E. L. M., del. ad nat.

Lith. Gottschalk, S. F.

PLATE 2.

Fig. 7. *Sagitta neglecta* Aida. × 3.

Fig. 8. *Eukrohnia hamata* (Möbius). × 3.

Fig. 9. *Eukrohnia subtilis* (Grassi). × 3.

Fig. 10. *Spadella draco* Krohn. × 8.

Fig. 11. *Sagitta tenuis* Conant. × 8.

Fig. 12. *Sagitta elegans* Verrill. × 3.

Fig. 13. *Sagitta arctica* Aurivillius. & 3.

ABBREVIATIONS

col.—collarette.

int.—intestine.

ov.—ovary.

seiz. j.—seizing jaws.

sem. v.—seminal vesicle.

vent. g.—ventral ganglion.

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PLATE 3.

Fig. 14. Left vestibular ridge of *Sagitta enflata.* × 240.

Fig. 15. Left vestibular ridge of *Sagitta hexaptera.* × 80.

Fig. 16. Left vestibular ridge of *Sagitta lyra.* × 80.

Fig. 17. Left vestibular ridge of *Sagitta gigantea* Broch. Specimen from Norwegian North Atlantic. × 80.

Fig. 18. Left vestibular ridge of *Sagitta bipunctata.* × 240.

Fig. 19. Double vestibular ridge of *Sagitta bipunctata.* × 240.

Fig. 20. Left vestibular ridge of *Sagitta serratodentata.* × 240.

Fig. 21. Left vestibular ridge of *Sagitta planktonis.* × 80.

Fig. 22. Left vestibular ridge of *Sagitta neglecta.* × 240.

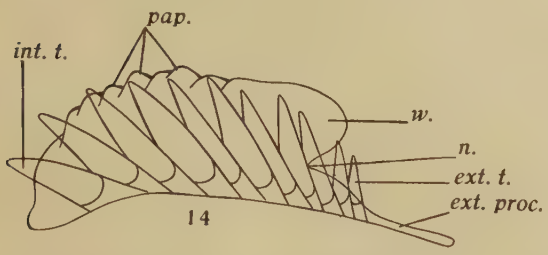
Fig. 23. Left vestibular ridge of *Spadella draco.* × 240.

Fig. 24. Left vestibular ridge of *Sagitta elegans.* × 240.

Fig. 25. Teeth of *Eukrohnia subtilis.* × 240.

ABBREVIATIONS.

b.—barbs.
ext. proc.—external process.
ext. t.—external tooth.
int. t.—internal tooth.
n.—notch.
pap.—papillae.
w.—wing of ridge.



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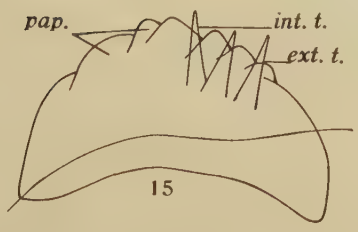

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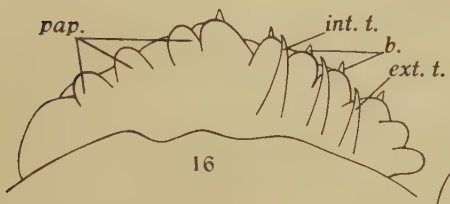

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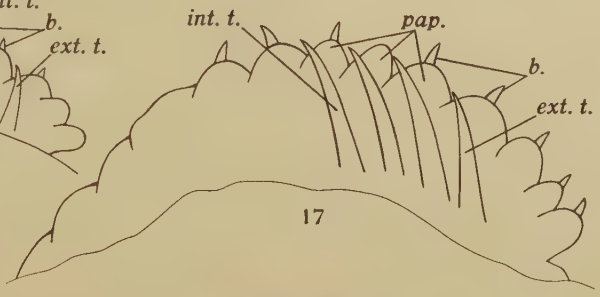

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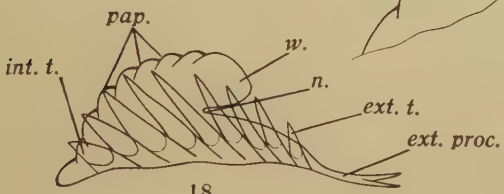

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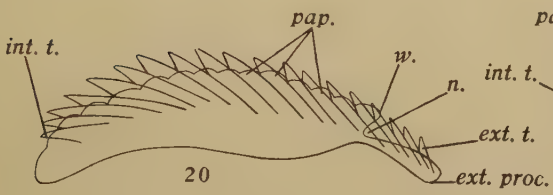

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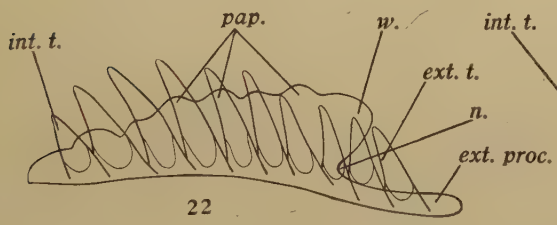

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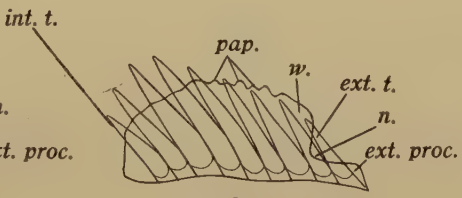

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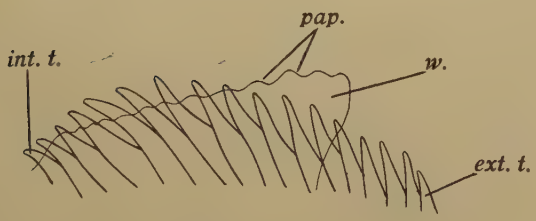

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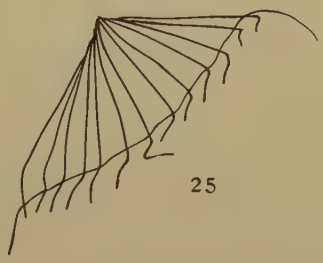

25

PLATE 4.

Fig. 26. Upper part of seizing jaw of *Sagitta enflata.* × 1130.

Fig. 27. Upper part of seizing jaw of *Sagitta hexaptera.* Old jaw. × 1130.

Fig. 28. Upper part of seizing jaw of *Sagitta hexaptera.* Young jaw. × 1130.

Fig. 29. Upper part of seizing jaw of *Sagitta lyra.* × 1130.

Fig. 30. Upper part of seizing jaw of *Sagitta serratodentata.* × 1130.

Fig. 31. Upper part of seizing jaw of *Sagitta bipunctata.* Old jaw. × 1130.

Fig. 32. Upper part of seizing jaw of *Sagitta bipunctata.* Young jaw. × 1130.

Fig. 33. Upper part of seizing jaw of *Sagitta planktonis.* × 1130.

Fig. 34. Upper part of seizing jaw of *Sagitta neglecta.* × 1130.

Fig. 35. Upper part of seizing jaw of *Eukrohnia hamata.* × 1130.

Fig. 36. Upper part of seizing jaw of *Eukrohnia subtilis.* × 1130.

Fig. 37. Upper part of seizing jaw of *Spadella draco.* × 1130.

Fig. 38. Upper part of seizing jaw of *Sagitta elegans.* × 1130.

ABBREVIATIONS.

b. pt.—base of point.

bk. sh.—back of shaft.

cr.—crest.

eg. sh.—edge of shaft.

p.—pulp.

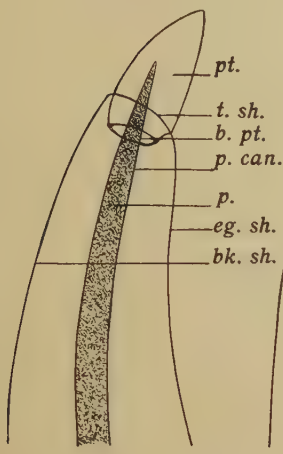
p. can.—pulp canal.

pt.—point.

ser.—serrations.

sw.—swollen place in pulp.

t. sh.—top of shaft.



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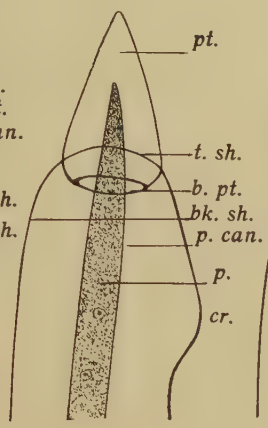

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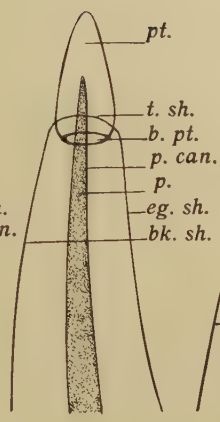

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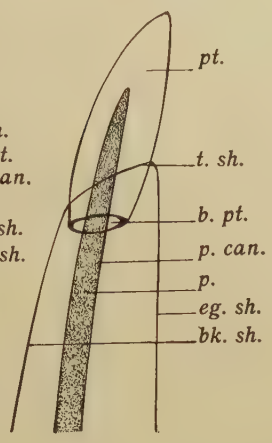

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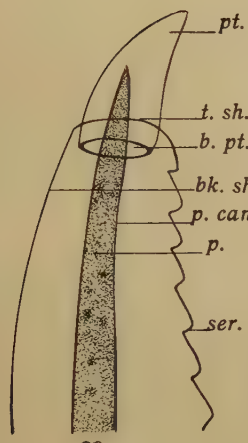

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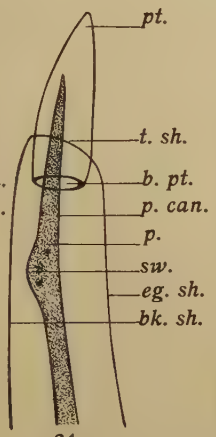

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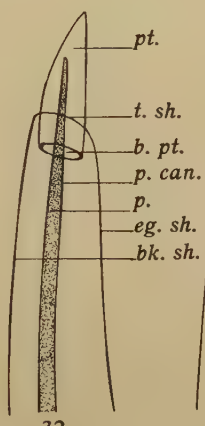

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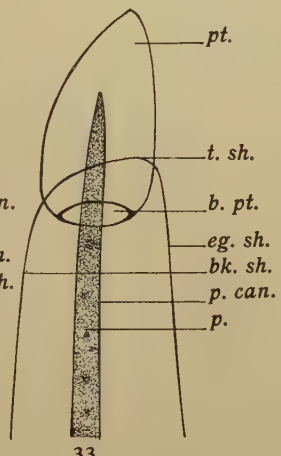

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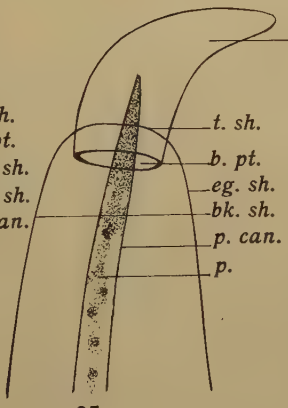

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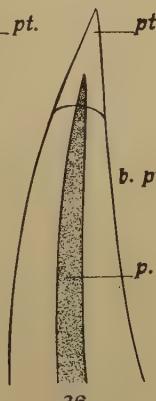

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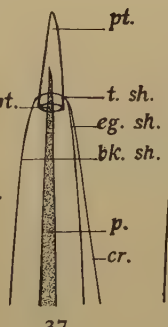

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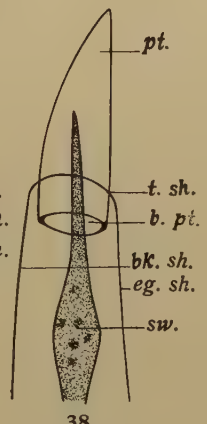


38

PLATE 5.

Fig. 39. Posterior end of *Sagitta enflata.* × 14.

Fig. 40. Posterior end of *Sagitta bipunctata.* × 14.

Fig. 41. Posterior end of *Sagitta serratodentata.* × 14.

Fig. 42. Posterior end of *Sagitta planktonis.* × 14.

ABBREVIATIONS.

ant. f.—anterior fin.

int.—intestine.

ov.—ovary.

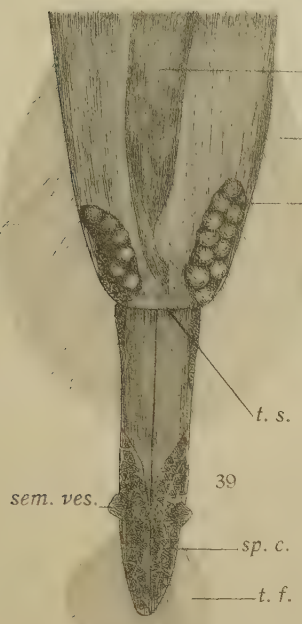
post. f.—posterior fin.

sem. rec.—seminal receptacle.

sem. ves.—seminal vesicle.

sp. c.—sperm cells.

t. f.—tail fin.



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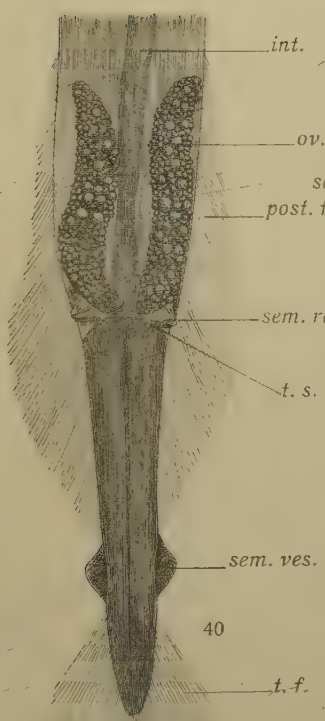

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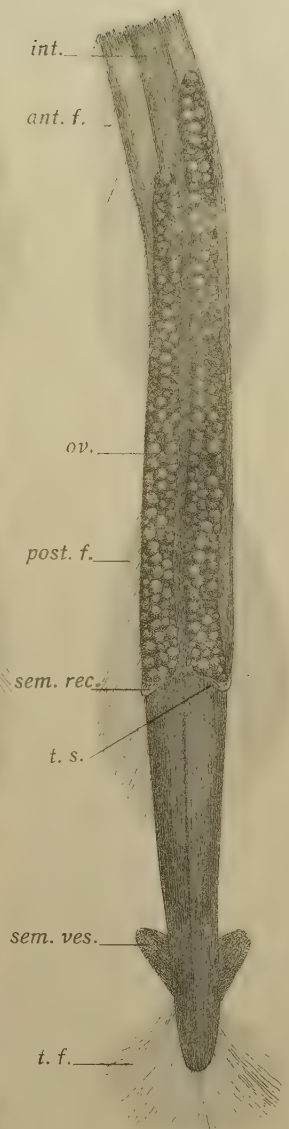


42

E. L. M., del. ad nat. Lith. Gottschalk, S. F.

PLATE 6.

Fig. 43. Posterior end of *Sagitta lyra*. × 6.

Fig. 44. Posterior end of *Sagitta hexaptera*. × 6.

ABBREVIATIONS.

ant. f.—anterior fin.

f. br.—fin-bridge.

int.—intestine.

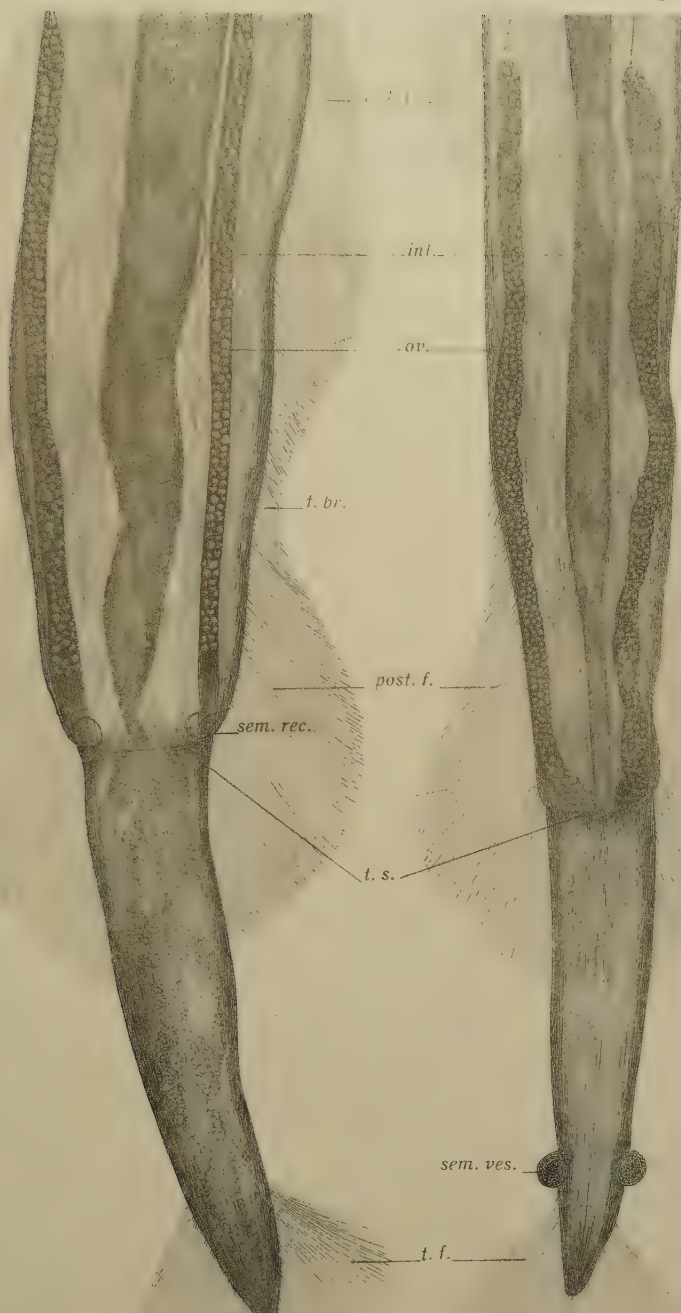
ov.—ovary.

post. f.—posterior fin.

sem. rec.—seminal receptacle.

sem. ves.—seminal vesicle.

t. f.—tail fin.



43 44

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PLATE 7.

Fig. 45. Head of *Sagitta enflata.* Dorsal view. × 40.

Fig. 46. Head of *Sagitta planktonis.* Dorsal view. × 40.

ABBREVIATIONS.

ad.—M. adductor uncinorum.

ant. t.—anterior teeth.

cl.—M. complexus lateralis.

col.—collarette.

cor. cil.—corona ciliata.

e.—eye.

es.—M. expansus superior.

int.—intestine.

ob.—M. obliquus capitis brevis.

ol.—M. obliquus capitis longus.

os.—M. obliquus superficialis.

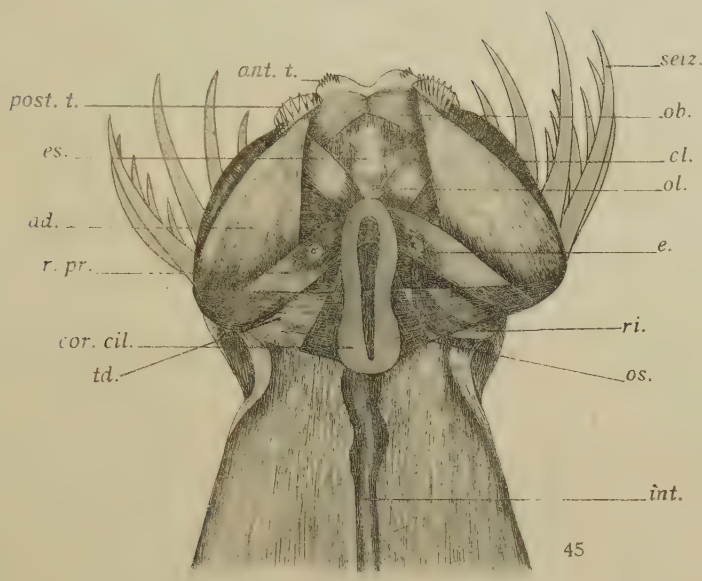
post. t.—posterior teeth.

ri.—M, rectus colli internus.

r. pr.—M. retractor praeputii.

seiz. j.—seizing jaws.

td.—M. transversus dorsalis.



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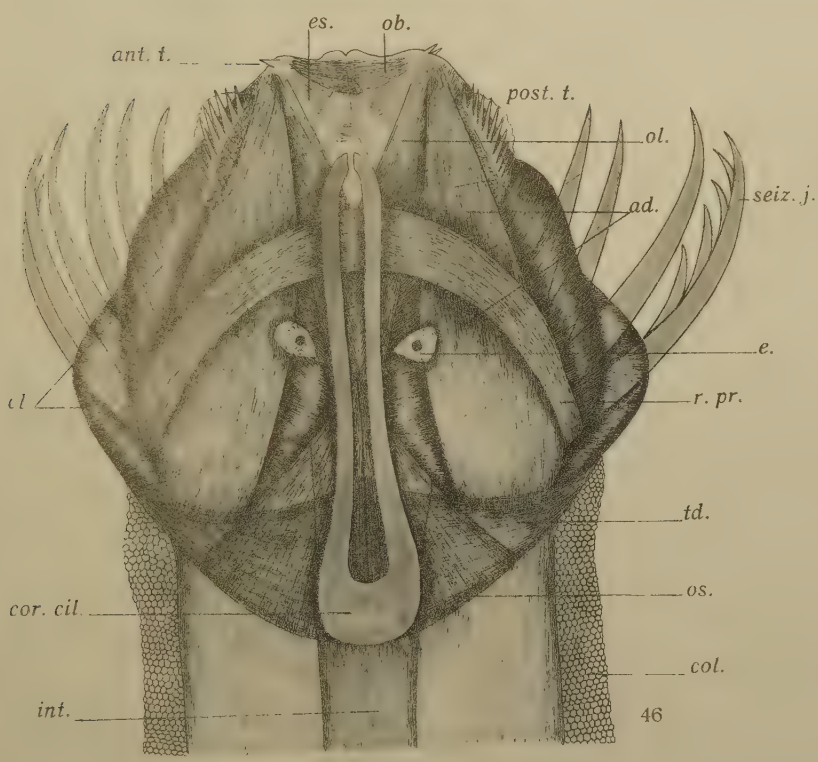


46

E. L. M., del. ad nat. Lith. Gottschalk, S. F.

PLATE 8.

Fig. 47. Head of *Sagitta enflata*. Ventral view. × 40.

Fig. 48. Head of *Sagitta planktonis*. Ventral view. × 40.

ABBREVIATIONS.

ant. t.—anterior teeth.

cl.—M complexus lateralis.

co. a.—M. constrictor oris alter.

col.—collarette.

co. p.—M. constrictor oris primus.

dv. e.—M. dilator vestibuli externus.

ei.—M. expansus inferior.

es.—M. expansus superior.

int.—intestine.

m.—mouth.

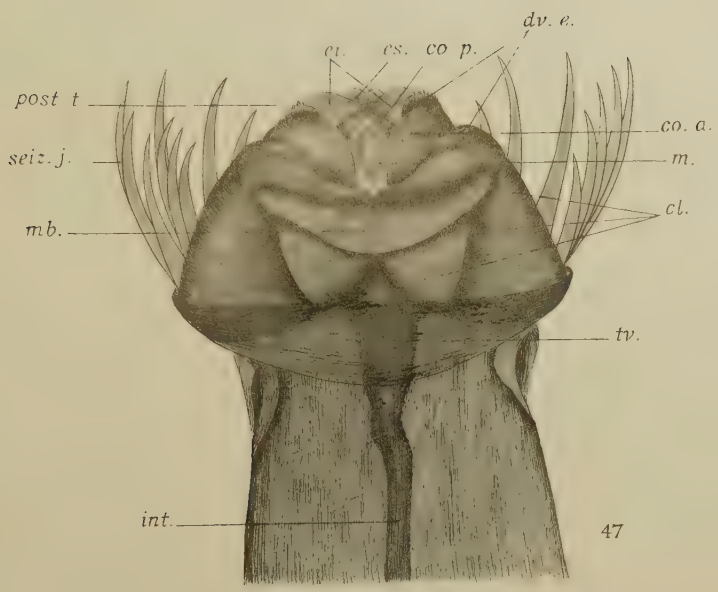
mb.—M. bicornis.

post. t.—posterior teeth.

p. pr.—M. protractor praeputii.

seiz. j.—seizing jaws.

tv.—M. transversus ventralis.



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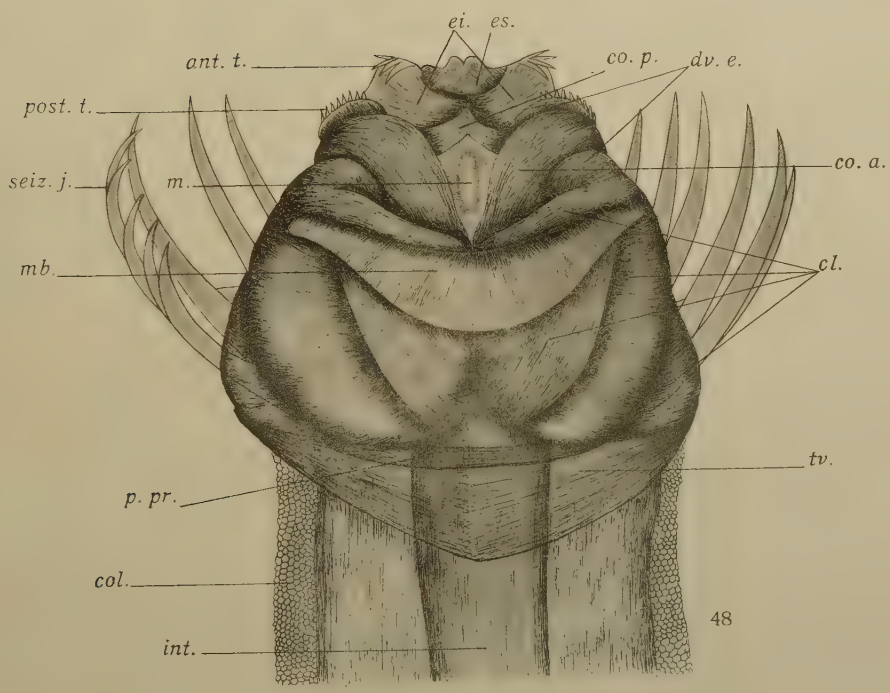

48

E. L. M., del. ad nat.

Lith. Gottschalk, S. F.

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